Co-UDlabs

Building Collaborative Urban Drainage research Labs communities

D1.1. Identification of RI users and UDS community needs

Date of delivery: 30/09/2022

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°101008626

DOCUMENT TRACKS DETAILS

Project acronym	Co-UDlabs
Project title	Building Collaborative Urban Drainage research labs communities
Starting date	01.05.2021
Duration	48 months
Call identifier	H2020-INFRAIA-2020-1
Grant Agreement No	101008626

Deliverable Information	
Deliverable number	D1.1
Work package number	1
Deliverable title	Identification of RI users and UDS community needs
Lead beneficiary	GRAIE
Author	Katharina Tondera, Fanny Fontanel, Elodie Brélot
Due date	30/09/2022
Actual submission date	30/09/2022
Type of deliverable	Report
Dissemination level	Public

VERSION MANAGEMENT

Revision history and quality check			
Version	Name	Date	Comment
V 0.1	Katharina Tondera, GRAIE	09/09/2022	First draft
V 0.2	Jose Anta, UDC	12/09/2022	Internal review
V1.0	Katharina Tondera, GRAIE	29/09/2022	Final version

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Background: about the Co-UDlabs Project

Co-UDlabs is an EU-funded project aiming to integrate research and innovation activities in the field of Urban Drainage Systems (UDS) to address pressing public health, flood risks and environmental challenges. It is a transnational and multidisciplinary "starting community" project, with the aim to influence European regulations and practices for a more sustainable management of stormwater in cities towards a more sustainable approach and more resilient management methods in the face of climate change.

Bringing together 17 unique research facilities, Co-UDlabs offers training and free access to a wide range of high-level scientific instruments, smart monitoring technologies and digital water analysis tools for advancing knowledge and innovation in Urban drainage systems.

Co-UDlabs aims to create a network of urban drainage large-scale facilities to provide opportunities for monitoring water quality, UDS performance and smart and open data approaches.

The main objective of the project is to provide a transnational multidisciplinary collaborative research infrastructure (RI) that will allow stakeholders, academic researchers, and innovators in the urban drainage water sector to come together, share ideas, co-produce project concepts and then benefit from access to top-class research infrastructures to develop, improve and demonstrate those concepts, thereby building a collaborative European Urban Drainage innovation community.

The initiative will facilitate the uptake of innovation in traditional buried pipe systems and newer green-blue infrastructure, with a focus on increasing the understanding of asset deterioration and improving system resilience.

Within the collaboration,

- experimental setups, technical innovations and knowledge from research institutions are shared with practitioners.
- practitioners and technical operators can exchange about their difficulties, their needs in terms of knowledge, technologies and training.
- practitioners can share their experience and expertise in the field in order to provide key elements to researchers
- the proposals built within the projects are nourished by the visions and needs of all partners from the different countries.

Through the different fields of expertise of the network members, this collective proposes a vision of the strong elements on which to intervene to improve Urban Drainage Systems (UDS) and to transition to Sustainable Urban Drainage Systems (Figure 1).

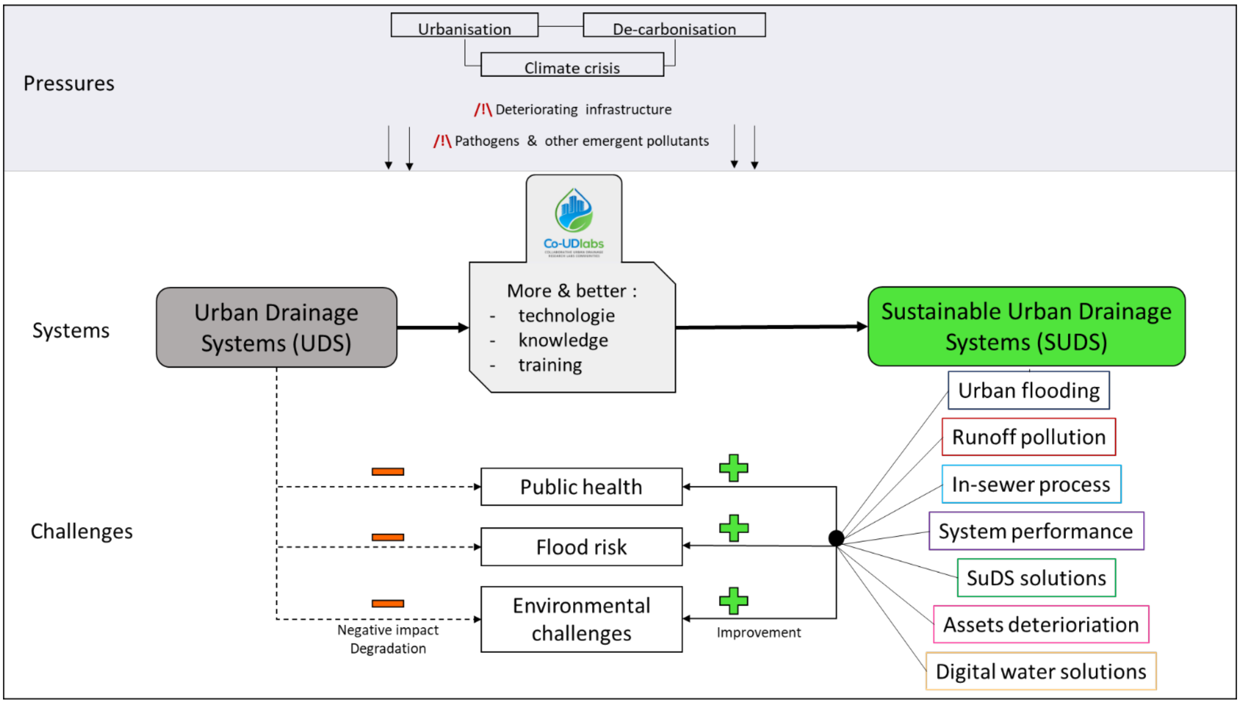


Figure 1. Common vision in the Co-UDlabs project.

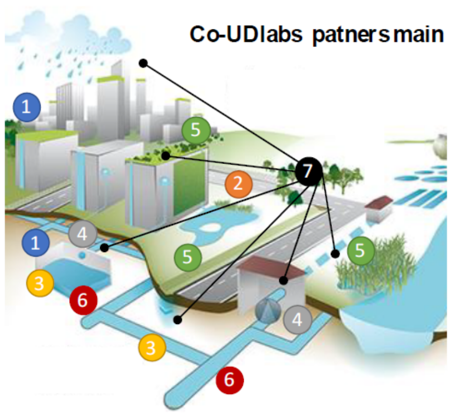
The themes of interest within the project are (Figure 2):

- Urban flooding,
- Runoff pollution,
- In-sewer processes,
- System performance,
- SUDS solutions,
- Assets deterioration, and
- Digital water solutions;

with the following approaches considered necessary:

- Improving and developing research and knowledge,
- Developing new technologies, and
- Training.

Co-UDlabs patners main research expertise areas



	UDC (SP)	UoS (UK)	DEL (NL)	EAWAG (CH)	IKT (D)	INSA (FR)	AaU (DK)
1 urban flooding	X	X			X		
2 runoff pollution	X	X				X	
3 in-sewer process	X	X	X	X			X
4 system performance	X	X	X	X	X	X	X
5 SuDS solutions	X				X	X	
6 assets deterioration		X			X		
7 digital water solutions	X	X	X	X	X	X	X

Figure 2: Main research areas and TA facilities offered by Co-UDlabs partners (adapted from Matzinger et al., 2017)

List of acronyms

Acronym / Abbreviation	Meaning / Full text
AMP	Asset Management Plan
CA	Consortium Agreement
DEFRA	Department of Food and Rural Affairs (UK)
DWMP	Drainage and Wastewater Management Plan (UK)
EA	Environment Agency
GA	Grant Agreement
IoT	Internet of Things
JRA	Joint Research Activity
NBS	Nature-based solutions
OFWAT	Water Services Regulation Authority (UK)
RI	Research Infrastructure
SDGs	Sustainable Development Goals
SUDS	Sustainable Urban Drainage Systems
SuDS	Sustainable Drainage Systems
TA	Transnational Access
UDS	Urban Drainage Systems
UK	United Kingdom
UKWIR	UK Water Industry Research
UWWTD	Urban Wastewater Treatment Directive
UWWTP	Urban Wastewater Treatment Plant
WaSCs	Water and Sewerage Companies (UK)
WFD	Water Framework Directive
WWTP	Wastewater treatment plant

Executive summary

This document is a Deliverable 1.1 “Identification of RI users and UDS community needs” of the Co-UDlabs project, funded under the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101008626. The Deliverable is drafted within the Work Package 1, “Sectorial Integration and Sustainability Strategy”. The lead beneficiary of the Work Package is the Group of Research, technical coordination and water information (GRAIE). GRAIE is the main author of this Deliverable.

The aim of this document is to collect and identify needs and visions from different stakeholders involved in the transitioning of Urban Drainage Systems within the European Union and associated countries towards sustainability and smart infrastructure. Therefore, different sources were considered: (i) policy documents existing in the countries represented in the project; (ii) inputs from the academic researchers and scientists involved in the Co-UDlabs project; and (iii) feedback from early adopters and (potential) users of the Research Infrastructure of urban drainage made accessible within the project.

The evaluation of the identified needs serves as a blueprint for a further identification of the role of Research Infrastructure in the research and innovation capacity needed to transition to more sustainable and smart urban drainage systems within the project. The aim of this report is to identify in a first step for which areas the different stakeholders define a need to be fulfilled that enables this transitioning.

1. Transitioning of Urban Drainage Systems – needs and visions

Up to the 1970s, the main approach in urban drainage was to evacuate rainfall from impermeable city environments as quickly and efficient as possible, often in combined sewers together with domestic and industrial wastewater. Increasing pipe diameters and network costs due to the ongoing urbanisation, as well as damages to the aquatic environments by the untreated discharges of stormwater and combined sewer overflows (CSO) initiated a paradigm change towards detention of stormwater and infiltration on site of low polluted runoff (Bertrand-Krajewski, 2021). Concepts from urban water management to a holistic urban water cycle management have been developed especially since the 1980s under different locally adapted terminologies, e.g. in Europe such as Integrated urban water management, Sustainable Urban Drainage Systems (SUDS) or Sustainable Drainage Systems (SuDS) and Alternative Techniques (Fletcher et al., 2015). Since the 1990s, a transition from first blue-green infrastructure to a holistic approach of integrating stormwater in the urban environment has taken place in order to make cities more liveable and restore water cycles while facing at the same time new societal and climatic challenges (Bertrand-Krajewski, 2021).

These challenges include demographic changes, urbanization and the climate crisis. While this field is not always in the focus of the public and policy makers, visionary documents on future developments within the water sector were published, e.g. by non-governmental organisations such as Water Europe and the International Water Association (IWA). The IWA Principles for Water Wise Cities (IWA, 2016) address explicitly urban stakeholders, whereas Water Europe's three interconnected publications Multiple Waters for Multiple Purposes and Users (Water Europe, 2016), the Strategy and Research Agenda (Water Europe SIRA, 2016) and Digitalisation and Water (Water Europe, 2021a) target more globally the European sector of research and development with a focus on marketability and systemic innovations. In the presented publications, the authors envision a future in which the challenges arising from water conflicts due to population growth, densification and climate crisis can be governed by a "water-smart society" (Water Europe, 2016) or, in other words, a "water-wise behaviour" (IWA, 2016).

IWA and Water Europe use similar concepts of referring to available water resources in the urban context, including surface waters and groundwater, polluted water and stormwater. In the IWA nomenclature, these are described as "Sustainable Urban Water", whereas Water Europe uses "Multiple Water". However, "Multiple Waters" can still contain pollutants since brackish and saline water, brines and used water belong to them, while "Sustainable Urban Water" has already undergone treatment ("desalinated water", "recycled water"). The general approaches to reach a water-smart societies relying on water-wise behaviour can be summarized as (IWA, 2016; Water Europe, 2016; Water Europe SIRA, 2016; Water Europe, 2021a):

- Taking the true value of water into account by encouraging a circular economy of water and valorising resources such as nutrients and energy from water. This should also enable to develop economically relevant new markets and business fields.
- Encouraging the development of new digital technologies (such as real-time monitoring approaches or AI data-driven models) to ensure the most efficient use of water (reduce water consumption, etc.).
- Developing "a hybrid grey and green water infrastructure" (Water Europe SIRA, 2016) by integrating nature-based solutions into traditional infrastructure in centralised and de-centralised solutions while respecting a circular economy approach, to benefit from eco-systemic services.
- Implementing new governance structures promoting multi-disciplinarity for better planning by creating cohesion between urban actors (from the expert to the inhabitant) and interactions between territories to enable synergies.

This holistic view of urban hydrology should encourage innovation, research and development of new digital technologies, nature-based solutions to move towards a more sustainable, resilient system and thus limit flood risks, improve urban water quality and ensure drinking water supply (Water Europe SIRA, 2016). Research

Infrastructures, such as the ones available within Co-UDlabs, are an opportunity to support the claimed "Hybrid green and grey water infrastructure" as they can help to develop and validate new urban drainage systems designs, experimental techniques and modelling approaches (data driven models, digital twins), to engage urban drainage actors in multi-sectorial teams around Transnational Access projects (thus contributing to avoid the fragmentation of green, grey and smart field of expertise) and also to exchange data and knowledge between the different stakeholders (Water Europe, 2021b).

However, the different disciplines and stakeholders involved in this development – academic researchers, industries, non-governmental organisations and decision-makers in administration and politics –, have different visions and needs regarding the future development of urban stormwater infrastructure, which additionally vary between regions and countries. One goal of the research project Co-UDlabs is to identify the connections and differences between these stakeholders and to propose adaptation strategies in order to support the transitioning of Urban Drainage Systems within the European Union and associated countries. This evaluation does not claim to be representative in a statistical sense, however, the aim of this report is to identify in a first step for which areas the different stakeholders define a need to be fulfilled that enables this transitioning. As sources for this needs evaluation, public documents from governmental and non-governmental institutions were consulted; additionally, opinions of the researchers involved in the project as well as from the interested general public were collected and analysed.

2. National “roadmaps” towards Sustainable Urban Drainage

The Co-UDlabs consortium comprises of members from five countries of the European Union (Denmark, France, Germany, Spain and the Netherlands) and two associated countries (Switzerland and United Kingdom). For each of these countries, we looked at legal and policy documents with respect to the current status and future development of urban drainage. The different legislative and executive structure of these countries required an expert approach on choosing the relevant publication, which was performed by the respective local participants within the project.

2.1. Denmark: High-level National lines of action

Author of this section: Jesper Ellerbæk Nielsen, Aalborg University, Denmark

2.1.1. National context

Operation and management of the Danish urban drainage and wastewater systems are divided among many utility companies, with a large diversity in size, age and design of systems and organization. However, the utility companies are responsible for securing clean drinking water, effective drainage and efficient wastewater treatment to protect human health, urban assets and the environment from risks and damages emanating from urban storm- and wastewater.

Environmental authorities define the boundaries within which the utility companies operate. On the national level, these consist of two ministries: The Ministry of Environment and Food in Denmark responsible for environmental regulation, and the Danish Ministry of Energy, Utilities and Climate responsible for the regulation of utilities and economic regulation of the sector. At the local level, the 98 municipalities are responsible for water and environment, including local water plans and compliance with legislation. They issue permits to the companies that are operating the utilities on a daily basis.

In 2007, the Danish parliament decided to introduce new legislation for a more efficient water sector, since it was difficult to separate the economical interactions between the utility and the municipality, and the parliament feared that the total costs of water for the consumer (used for water distribution, water treatment and climate adaptation) were unreasonably high. This was a significant change in the ownership and benchmarking of the utilities in Denmark. The utilities were legally and economically separated from the municipality following the new principle that no utility should be able to generate a profit from their activity[1]. Consequently, all utilities undergo a **benchmarking** every year to set a price for water consumption – and thereby for activities of wastewater treatment, rainwater management and climate adaptation.

The benchmarking is related to the average costs of all utilities in Denmark and is calculated based on the sum of operation and construction costs of the water infrastructure. If the utilities have a higher cost profile than the average, they are required to cut costs by up to 2% the following year[2].

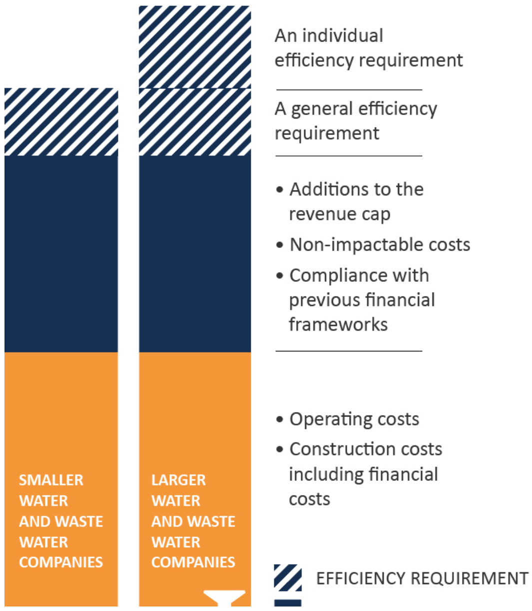


Figure 3: Model for revenue cap for smaller and larger utilities (Source: Danish Consumer and Competition Authority, 2022)

[1] https://www.en.kfst.dk/water-regulation/revenue-caps/

[2] Details can be found at: https://www.en.kfst.dk/water-regulation/benchmarking/

The **Water Pollution Committee** of The Society of Danish Engineers was formed in 1944 and has played an important role in the development of urban drainage and wastewater technology in Denmark. The Water Pollution Committee has taken the initiative for research and development projects and published guidelines for urban water managers.

The Water Pollution Committee[3] is a consensus-based organization and consists of volunteer members from municipalities, utility companies, consulting engineer companies, other related industries, and Danish Universities. The guidelines published by the Committee have formed the background for the common practice in urban drainage in Denmark, and they have been a crucial prerequisite for the design and development of professional practice within storm- and wastewater management in Denmark.

As an example, in the seventies, the Committee decided to establish a national rain gauge network, dedicated design and planning of urban drainage systems, because at that time, only a few automated rain gauges were capable of measuring the rainfall intensity with high temporal resolution. Today, the network consists of approximately 160 rain gauges that are individually owned by the utility companies, whereas the network is managed and maintained by the Water Pollution Committee. The rainfall observations from the network are evaluated and processed at regular intervals by the Committee and have since its establishment formed the basis for rainfall statistics and design practices of drainage systems in Denmark.

The **Danish Water and Wastewater Association (DANVA)**[4] is the industry organization for Danish water and wastewater utility companies and an interest organization for the Danish water sector and water and wastewater professionals in general. The association is an independent non-profit association, financed by the members and by revenue-generating activities. The organization focuses on uniting all the actors in the water cycle collaborating for sustainable solutions for the benefit of consumers, the environment, society and utilities with the goal to strengthen consumer confidence in water, efficient operation and high security of supply.

2.1.2. Guidelines and lines of action

The roles and responsibilities of public bodies concerning sewerage and wastewater treatment are defined in the following main legislation:

- Danish Water Sector Reform Act
- Act on Payment Rules for Wastewater
- Consumer Complaint Act
- Act on Liability for Environmental Damage
- Wastewater Charges Act
- Act on Water Planning
- Watercourses Act

However, as described above, in Denmark, the guidelines for the engineering implementation of the best design and management practice are based on consensus guidelines published by the Water Pollution Committee.

The high-level National lines of action are oriented around the UN Sustainable Development Goals (SDGs), focusing on sustainable development of the water sector, with solutions that balance the environmental impact as well as urban and societal developments. As in many other European countries, climate change, climate adaptation and increased environmental awareness are subject to discussion among politicians, experts and the public. The impact of the ongoing climate change is stressing the existing urban drainage systems, increasing the risk of flooding and the frequency of combined sewer overflows. At the same time public awareness of the environmental impact of

[3] https://ida.dk/om-ida/spildevandskomiteen
[4] https://www.danva.dk/

urban areas demands reduced discharge permits reducing this impact. This generates competition between climate mitigation and environmental impact and challenges the sustainable solution without compromising the capacity safety the system. The general increased awareness of the environmental impact from combines sewer overflow has created attention on quantifying their amount and composition on a national scale.

Also, in recent years, several water utility companies in Denmark have experienced that stormwater runoff from urban areas has started to vary significantly depending on the season. The Danish winters have become wetter with more rainfall than previously, therefore, the soil tends to be more saturated during winter, which changes the urban hydrology and increases the active stormwater runoff surfaces by including semipermeable and permeable surfaces, where rainfall normally infiltrates. This has put focus on methods, measurements and models that can predict the situation-dependent runoff.

2.1.3. Putting the Co-UDlabs project into perspective

The subjects covered by Co-UDlabs are in many aspects aligned with national initiatives for UD developments.

Knowledge in terms of monitoring data is needed to support the UD systems development and assessment of long-term system performance and response to climate change. In this context, sustainable solution elements and the understanding and prediction of how they perform in long term are needed for the design and development of high quality and reliable solutions. In Co-UDlabs this is aligned with the activities in WP6 and WP7.

SUDS applications are subject to further development in terms of **guidelines**. Here, monitoring methods are needed to assess the long-term behaviour, as these solutions often are left unmonitored after construction. The experimental facilities offered in Co-UDlabs match this and are aligned with the activities in WP8.

2.2. France: the 2022-2024 Stormwater Action Plan

Authors of this section: Fanny Fontanel, GRAIE, Frédéric Cherqui, INSA Lyon, Elodie Brelot, GRAIE, France

2.2.1. National context

In France as elsewhere, water issues are one of the major challenges identified in the face of climate change. This resource is vital, but water is also a source of major risks, particularly in urban areas (flooding, intense runoff, polluted water, etc.). Through regulations in the fields of urban planning, the environment and water, the State is committed to working with local decision-makers to change the way cities are being built in order to make them more resilient to climate change.

Spatial planning is chosen as fundamental lever for limiting water-related impacts and risks and for adapting to climate change. A recently enacted law contains, among others, the goal of reducing the net new land consumption to zero by 2050[5]. This should be reached by reducing the net new land consumption by half every decade compared to the precedent one, while at the same time privileging the infiltration and evaporation of rainwater.

In terms of water policy, in 2015, the NOTRe law[6] established a new specific competence, the GEPU - Gestion des Eaux Pluviales Urbaines (Urban Stormwater Management) - and helped evolving the distribution of drinking water and sanitation competences by moving them from single municipalities to cooperation of municipalities, implying a mutualisation of technical competences at this territorial scale. The clustering of services is particularly relevant: in 2015, there were more than 33’000 services dedicated to drinking water or drainage[7], this number has decreased to 26’000 in 2020[8]. The clustering will continue in the next year: it enables services to reach a sufficient size for resources dedicated to the management of the system. At the same time, the General Council for the Environment

5 https://www.legifrance.gouv.fr/loda/id/JORFTEXT000045197395/
6 https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000030985460/
7 https://www.services.eaufrance.fr/docs/synthese/rapports/Rapport_SISPEA_2015_complet_DEF.pdf
8 https://www.services.eaufrance.fr/docs/synthese/rapports/Rapport_Sispea_2020_VF.pdf

and Sustainable Development (CGEDD), responsible for evaluating public policies and advising ministries, carried out a major national consultation with practitioners and scientists on stormwater management in France. In 2019, the State led a major consultation with all stakeholders in the framework of the "Assises de l'eau" (water conferences), which also put forward recommendations on stormwater management policy.

One of the major regulatory difficulties for stormwater management in France is its complexity: many regulations exist, many documents and standards are available to territorial actors to better manage stormwater in a sustainable way, but it is difficult for a non-specialist to get an overview. However, there is a strong need expressed by all ministries and departments concerned, to reduce imperviousness and promote the infiltration of rainwater.

Regulatory developments are converging towards the establishment of a strategy at the interface of water management and planning: to promote "integrated stormwater management to make cities sustainable and resilient by encouraging infiltration of rainwater at source" (MTE, 2021). For this reason, the Ministry of Ecological Transition has established an action plan for 2022-2024 in a concerted manner between the State services (directorates of local authorities, urban planning, risks, water and the environment) by associating the institutions and scientific and technical associations involved in this field, entitled: "To accelerate the sustainable management of rainwater on a national scale". This plan proposes a set of concrete actions to really drive the necessary transition.

2.2.2. Guidelines and lines of action

The Secretary of State for Biodiversity presented the national action plan to the Ministry of Ecological Transition in November 2021. She positioned the action plan as a response to the two major pressures of climate change and increasing urbanisation. This is why she insists on the need for collaboration, stressing that this is a "collective challenge", which is reflected in the four axes of the plan:

- Integrating stormwater into development policies
- Raising awareness of the challenges and benefits of managing rainwater at source
- Facilitating urban stormwater governance and policing
- Improving scientific knowledge

Axis 1: "Integrate stormwater management into land-use planning policies, by improving collaboration between water and land-use planning stakeholders”

The proposed actions consist in particular in setting up in 2022 a "water in the city" resource centre with a stormwater management section to facilitate the transfer of knowledge and the sharing of experiences between the various stakeholders concerned: decision-makers, local authority agents, technical service providers in the fields of development, urban planning, landscape, construction and water. Another key action is to accompany the implementation of the regulation before 2026, in order to generalise planning documents on stormwater management zones and to integrate them into the general urban planning.

Axis 2: "Increase awareness of stormwater and the services it provides, based on feedback".

The proposed actions concern in particular training for the various target audiences: elected decision-makers, community practitioners and service providers. Awareness-raising actions and animating networks of professionals should better support local authorities and increase the skills of design offices in the field of stormwater management. It is also a question of highlighting virtuous operations through observatories and calls for projects.

Axis 3: "Facilitate and support the exercise of the water police and the GEPU competence to improve the management of networks during rainy weather".

The GEPU competence - urban stormwater management - was recently established with ill-defined contours, which are problematic for the communities. The interaction between the different water competences, i.e. 1 - urban stormwater, 2 - management of aquatic environments and flood risk prevention, and 3 - sanitation, but also between the competences of urban planning, roads and green spaces, needs to be clarified. Moreover, the regulations must be revised regarding urban rainfall discharges into natural environments and the State services in charge of examining the files must be made aware of the evolution of the issues and strategies. Finally, the management of assets is at the heart of this axis, with actions proposed to strengthen the knowledge of existing assets.

Axis 4: Improving scientific knowledge for better stormwater management

Research and development of scientific knowledge have an important place in this action plan, relying in particular on the three French scientific observatories in urban hydrology, namely OTHU in Lyon, OPUR in the Paris region and ONEVU in Nantes. The main areas identified are:

- Characterising urban rainfall discharges through better management of self-monitoring databases;
- Continuing research on the sources of pollution, their transfer via the network, accumulation in the structures and the management of sediments; and
- Increasing the number of observatories and demonstrators on source management solutions.

2.2.3. Putting the Co-UDlabs project into perspective

This action plan highlights the main needs expressed by the ministry, in consultation with a part of the scientific and technical community, to deploy a sustainable stormwater management strategy on the national territory. Many of the needs expressed are fully in line with the objectives and vision of the Co-UDlabs project partners.

Nature-based solutions are developing in France and are increasingly used in urban areas to manage stormwater, particularly because of the multiple related, intrinsic and fundamental benefits in the face of climate change: resilience of solutions, fight against heat islands, increase of biodiversity and well-being, etc. Nevertheless, in order to implement these solutions, decision-makers as well as water and land use professionals need to be trained and made aware of the advantages of these solutions and the necessary paradigm shift, in order to overcome a centralised end-of-pipe mentality historically proposed by engineers.

Experimenting with and improving the performance of NBS is a strong focus of the Co-UDlabs project. Several projects presented at the Hackathon organised by Co-UDlabs in November 2021 were related to this theme, in particular the selected project that investigates the potential of these structures in extreme climates (very hot or very cold). In the Co-UDlabs project, three research institutes are providing facilities of this type for “Transnational Access”, such as INSA Lyon via the OTHU (porous pavements, infiltration trenches and ditches, and green roofs).

The French roadmap expresses important needs in terms of **scientific knowledge**, particularly concerning centralised systems (networks and basins). It focuses on the following themes:

- Characterization of stormwater pollution, its transfer and impacts on receiving environments;
- Operation, performance and exploitation of centralised systems, with a focus on sludge; and
- Data acquisition and processing for optimised asset management.

These research directions are in line with those proposed in the Co-UDlabs project and highlighted at the IKT workshop of November 4, 2021 on "Good practices and research needs for optimising urban stormwater", with the possible exception of technological developments, which are not explicitly expected.

The roadmap insists on the need to train the different actors involved in stormwater management and to raise their awareness of the topic, but also with a broader view on nature-based solutions. It identifies three target audiences:

- Elected officials and decision-makers;
- Technical actors in city construction (urban planners, land developers, landscape architects, etc.); and
- Technical actors in water management (operators, design offices, suppliers and public works companies).

Training is a strong focus of the Co-UDlabs project, targeting the urban hydrology community, especially on monitoring and metrology (self-monitoring). An opening to less specialised and less technical audiences could be studied.

The two strong orientations of the French roadmap, not very developed in the framework of Co-UDlabs are:

- Awareness raising and training of non-specialists, especially for the development of source solutions, due to their multi-functionality and the necessary involvement of all actors, apart from only technical actors in sanitation. Knowing that Co-UDlabs researchers and devices integrate these solutions at source, this opening towards other audiences could be considered.
- Development of demonstrators and observatories, to show full-scale achievements, again to non-specialists and unconvinced audiences. Our research facilities could very well integrate awareness-raising programmes and be open to visits by non-specialists to facilitate the adoption of these solutions.

The French strategy for stormwater management is intended to be fully integrated with land use planning, in the spirit of the principles for water-wise cities. It is proactive in encouraging local authorities and private developers to implement stormwater management solutions at the source, and moreover solutions based on nature. To achieve this, the key challenge is to mobilise the actors involved in city planning, hence the term "collective challenge" used earlier.

2.3. Germany: National Water Strategy

Authors of this section: Thomas Brüggemann, IKT Gelsenkirchen, Germany; Iain Naismith, IKT, Office Wathlington, UK; Marcel Goerke, IKT Gelsenkirchen, Germany

2.3.1. National context

Germany is also facing major challenges in water management. In particular, the consequences of climate change and the necessary measures are the subject of intense discussion among politicians, experts and the public, especially regarding the increase in localised heavy rainfall events and their consequences for urban areas. Other major challenges - as in other European countries – include the ageing infrastructure of wastewater and stormwater disposal and the growing number of environmental pollutants, including the increased detection of microplastics and trace substances in water bodies, which are reflected in corresponding position papers, studies and expressions of interest by the German water association DWA and by other organisations (DWA, 2018; 2021a; 2021b; IWW-FiW-IKT, 2019).

The federal structure of Germany is also reflected in "The Federal Water Resources Act" (Wasserhaushaltsgesetz WHG) (WHG, 2009), which transposes the requirements of the European Water Framework Directive (EU WFD) into national law. It provides the framework for water legislation in Germany and regulates the protection and use of groundwater and surface waters. In addition, the Federal Water Resources Act also defines general requirements for wastewater disposal, e.g., that wastewater facilities must be constructed, operated and maintained in accordance with the generally recognised rules of technology. The water laws and ordinances of the 16 federal states supplement and enforce the federal water legislation. For example, with regard to wastewater disposal, in some cases very specific requirements are made regarding the scope of monitoring of the sewer system and its structures.

The enforcement of water legislation is decentralised at the municipal level, as the municipalities are responsible for wastewater disposal. Municipal wastewater companies or wastewater associations of several municipalities organise wastewater disposal for member municipalities. In addition, there are also special statutory water management associations in Germany, such as the Emschergenossenschaft and the Ruhrverband. These are river basin-related organisations, which - in addition to the municipalities in the association's area - assume part of the water management tasks, such as flood protection, wastewater transport and treatment, and watercourse maintenance.

Due to the decentralised and partly also locally specific organisation of German wastewater and stormwater disposal, and in view of the challenges of the future, close cooperation between the stakeholders involved is needed more than ever. Particularly with regard to the large-scale implementation of climate impact adaptation measures following the sponge city principle, close cooperation between all involved stakeholders in densely populated areas is required. A positive example here is the Ruhr area, one of the largest metropolitan areas in Europe with more than 5 million inhabitants. In the Ruhr area, the initiative for the future KLIMA.WERK (EGLV, 2021) was concluded between the Emschergenossenschaft water board, 16 cities and the State of North Rhine-Westphalia. The goal is to create sponge cities that can withstand weather extremes. KLIMA.WERK implements near-natural rainwater management in the water management catchment area of the Emscher River (Figure 4).

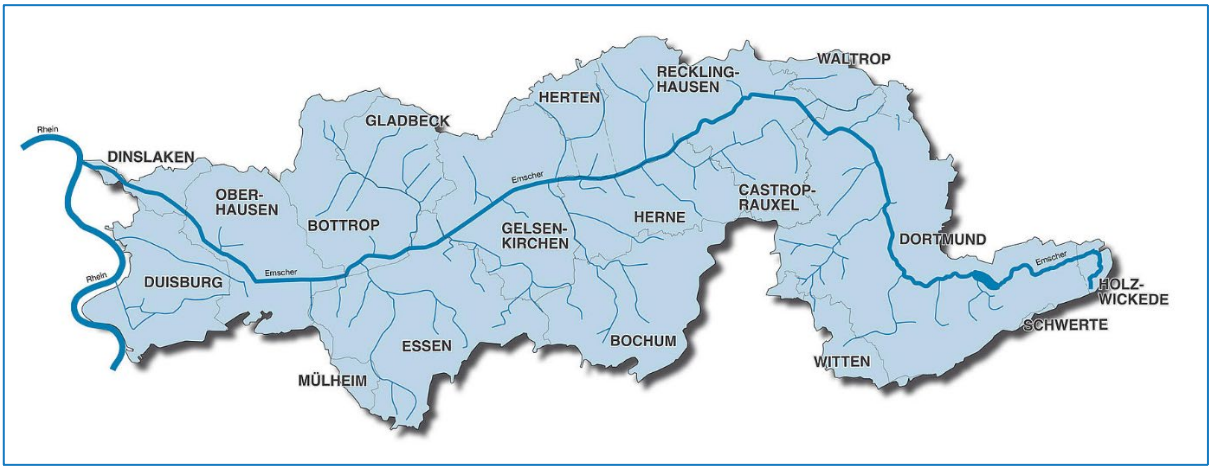


Figure 4. Emscher River catchment area in the Ruhr valley, Germany (Source: Emschergenossenschaft)

However, this kind of cooperation is not a matter of course. Implementing measures for near-natural rainwater management, such as constructing infiltration systems and infiltration trenches, installing of green roofs, and unsealing of impermeable surfaces, can create difficulties at the municipal level since several stakeholders of the city administration have to be involved, such as the wastewater company, spatial planning, road and civil engineering, property owners, supervisory authorities.

2.3.2. Guidelines and lines of action

The National Water Strategy of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) addresses the problems described above. In June 2021, a draft version of this national water strategy was published (BMU, 2021). However, this draft is only a basis for further discussions and coordination in Germany.

The foreword to the National Water Strategy points out that the pressure on water as a resource is increasing. Fundamental causes and challenges are mentioned here:

1) Climate change: drought and heavy rainfall
2) Environmental policy: pollution of water bodies by nitrate, phosphorus and a multitude of other substances.
3) Developments such as digitalisation, changes in lifestyle and land use

In general, the following ten strategic themes are described for water management (water supply, wastewater/stormwater disposal and water protection) as being challenges, visions and transformations towards sustainable water management:

- strengthening awareness of water as a resource
- further developing water infrastructures

- linking water, energy and material cycles
- limiting risks from substance inputs
- restoring and managing the natural water balance - preventing conflicting objectives
- implementing water-compatible and climate-adapted land use in urban and rural areas
- further developing sustainable water management
- protecting marine areas (North Sea and Baltic Sea) more intensively against material discharges from the land
- strengthening efficient administrations, improving data flows, optimising regulatory frameworks and securing funding
- protecting global water resources sustainably together

With regard to the challenges of urban drainage, the following measures in particular can be identified in the National Water Strategy (BMU, 2021):

Strengthen awareness of water as a resource

- Development and implementation of a long-term communication strategy aiming at different target groups, including: "importance of wastewater disposal", "adaptation to climate change", "rainwater infiltration".
- Training programme for local politicians: Establishment of training and further education programmes for municipal policy-makers with content on planning aspects, ecological and technical points.
- Network of places of experience and learning: Creation of a nationwide network of educational institutions, places of experience and of learning with a focus on water for the promotion of young people.

Develop the water infrastructure further

- Developing of nationwide guidelines for the future design of water infrastructures to support administrations and infrastructure operators in long-term cross-sectoral infrastructure design (e.g., unsealing, adaptation to climate change)
- Making water management (technical) regulations climate-proof
- Supporting the creation of hazard and risk maps for local heavy rainfall events through a standardisation guide.

Link water, energy and material cycles

- Developing of "assistance" for water sector coupling: On the basis of existing research results and pilot projects, manuals will be developed for infrastructure operators ("showing what is feasible") to facilitate the creation of sector-coupled, climate-neutral and resource-efficient wastewater systems. This includes technical, legal, financial and organisational aspects.
- Requirement 5. Restore and manage the natural water balance:
- Near-natural rainwater management: The prioritising of near-natural rainwater management measures* (e.g., infiltration and evaporation) is to be strengthened in communal urban land use planning. In the case of infiltration, the pollutant load of rainwater is to be taken into account to protect groundwater from contamination. This serves to implement water-sensitive urban development.

Implement water-compatible and climate-adapted land use in urban and rural areas

- Further development of the model of the "waterwise city" (sponge city) and put it into practice.

Develop sustainable water management further

- Improve the ability to integrate water management planning into overall spatial planning.

Strengthen efficient administration, improve data flows, optimise regulatory framework and secure funding

- Further development of inter-municipal cooperation in wastewater disposal
- Strengthen the administration in terms of personnel and organisation
- Design a water data strategy

Jointly protect global water resources sustainably

- Cooperation in the international implementation of sustainable water resource management, support in establishing structures and capacities for joint data management and knowledge transfer measures, among other things

2.3.3. Putting the Co-UDlabs project into perspective

Many of the aspects of Germany's National Water Strategy are also reflected in the CO-UDlabs project. The topic of **nature-based solutions / waterwise urban development** (e.g., rainwater infiltration and basins) is addressed several times in the National Water Strategy and is also a main topic of the CO-UDlabs project. In addition, the pollutant load in rainwater is also addressed. This topic is taken up experimentally in JRA3 of Co-UDlabs.

Public relations and the promotion of young people are also mentioned as important components in the National Water Strategy. In this context, it is also pointed out that political decision-makers must be familiarised with the contents of water management. Training and further education are also aspects of Co-UDlabs.

The international **exchange of knowledge and uniform international data management** are goals formulated in the National Water Strategy. This is also an elementary component of Co-UDlabs.

The National Water Strategy in Germany does not directly address the deterioration of the wastewater infrastructure and the associated necessary maintenance strategies. However, this topic is of fundamental importance for the future viability of water management, as studies in Germany have shown (Berger et al., 2020, IWW-FiW-IKT, 2019) and was therefore necessarily set as a focus in the CO-UDlabs research project.

2.4. Spain: stormwater management needs to be included in the National Water Plan

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2.4.1. National context

The Spanish national legislative framework on water was initially established in the 19th century when the first Water Acts were approved in 1866 and 1879. The current Water Act has been in force since 1985; it was established a few years after recovery of democracy. This law presents the legal framework for water quantity, uses, protection, and planning within the river basins that are directly managed by the central administration. However, this law does not have any specific aspects regarding stormwater management or urban drainage.

Spain’s water governance system addresses 21st century water challenges (increased water demand, decreased availability of water resources, increased quality standards) via water-resource planning by means of a River Basin District approach according to the EU WFD. At national level, some river basins are managed by the Spanish government, and others are managed by regional governments. At this highest level of water management, new water demands and available resources are studied, structural and non-structural actions are defined and prioritized (e.g. river regulation, new unconventional resources such as desalination or rainwater harvesting), and measures to improve and guarantee aquatic ecosystems status are defined and monitored. High-level planning and management also consider extreme events such as droughts and floods, affected by the context of climate change.

Urban water (water supply, urban drainage, wastewater treatment) is managed by the different councils and metropolitan areas according to dozens of regulations at national, regional and municipal level. Regarding urban wastewater (and stormwater) transport and treatment, a harmonised governance scheme is still missing, and the River Basin District approach is not applied in some large urban agglomerations in which different councils are involved. Many water utilities, with different size, expertise, from the public or private sector, are involved in the management of wastewater and urban drainage systems. Design criteria and management practices vary across the country, and even within the same River Basin Districts. Thus, the urban water sector is very fragmented at all levels.

The governance structure of the water sector in Spain is described in the Green Book of the Spanish Minister of Ecological Transition (Gobierno de España, 2020). At national level, the Spanish Association of Water Supply and Wastewater Treatment has published a series of technical guidelines related to wastewater services (FEMP, 2014). As previously mentioned, municipal authorities are the responsible of wastewater and water supply services provision. In some cases, the water services are managed using an integrated approach, especially in large cities, but their management is usually fragmented among several entities and water operators.

2.4.2. Guidelines and lines of action

In Spain, a national roadmap or a vision document about the urban water sector is missing. In order to define the main guidelines and lines of action, a comprehensive review of different level guidelines, regulations and recommendations was performed. The main documents summarized in the following range from a general national–state perspective (Gobierno de España, 2020), through the urban context stated in the Spanish Urban Agenda (Ministerio de Fomento, 2018), the scope of service provision defined by the Canal Isabel II Foundation – the biggest Spanish water company based in Madrid (Delacámara et al., 2017), to the vision of more focused regulations on wastewater, drainage and urban flooding (Ministerio para la Transición Ecológica, 2019; Andrés-Doménech, 2021).

The main challenges defined in the Spanish Green Book of Governance are (Gobierno de España, 2020):

- The adaptation of the current regulatory framework
- The strength of the organizational and financial structure of the water sector
- The improvement of the coordination and cooperation among the different administration levels
- The improvement of the decision making (evidence-based), water digitalization and water knowledge
- The implementation of an integral urban water perspective, ensuring financial resources to assure water quality in a mid- and long-term perspective.

According to the analysis of the Green Book, the new governance model for urban water may consider a new way of integrating water services in the city, as well as citizens' opinion. In the field of urban drainage, urban flooding and pollution impacts related to weather flows must be included in the analysis of water systems. New nature-based solutions are being promoted. Furthermore, the publication also states the main economy-scale problems, which does not allow small municipalities to provide services at reasonable costs, nor to establish controls on the quality of the service. This has led to the outsourcing of the service to water utilities, with the consequent decapitalization and loss of information on water management.

The main action lines to deal with urban water services highlighted in the **Spanish Urban Agenda** (Ministerio de Fomento, 2018) are consistent with the vision of the Green Book: (i) Regulatory Framework, (ii) Urban planning – water management, (iii) Governance and (iv) Water digitization. The Spanish Urban Agenda defines 30 strategic action objectives aligned with Sustainable Development Goals and 2030 Agenda (UN, 2015). The main objectives for the field of urban drainage are defined below, with a short summary of specific measures to be taken:

- **To prevent and mitigate climate change impacts and to improve urban resilience:** urban planning and soil sealing measures and regulations, reduction of greenhouse gases, flooding mitigation and flood risk analysis, incorporation of green and blue-green infrastructures, reduction of heat island effect in the cities, public scrutiny of actions, public education measures.

- **To enhance a sustainable resource management and to favor circular economy:** energy and water supply efficiency, water reuse, rainwater harvesting, implementation of grey water systems in the buildings, promotion of separate sewer systems, promotion of SuDS.

The perspective of the water utilities in Spain was considered in Delacámara et al. (2017). The main challenges and opportunities highlighted in this report are:

- **Lack of financial resources:** need of a new tax-system, for assets management and asset rehabilitation.
- **Lack of economies of scale:** the sector comprises more than 8000 municipalities and 2800 provision services. Urban water sector will benefit from "communities of users"[9] to provide water services
- **Lack of a clear regulation body,** with multiple actors working at different levels
- **Water quality challenge:** although wastewater treatment is progressing according to EU WFD and UWWTD, stormwater treatment, combined sewer overflows and wet-weather impacts on WTTP pose unsolved problems, as well as of emerging pollutants (e.g., PCPPs, microplastics).
- **Improving public perception in terms of transparency and management models:** public vs private water services provision debates deviate citizens from the key issues - they must understand what the services provided consist of, what benefits they receive and at what costs.

Regarding the normative framework, after the transposition of EU UWWTD, the most relevant milestone in Spanish urban drainage was the modification of the regulations for the public domain of 2012. Since this date, the management of combined sewer overflows during rainy events is considered in the regulatory framework, including (i) an analysis if separate or combined sewer networks are more favourable, (ii) the adoption of measures to limit combined sewer overflows and separate sewer discharge, and, (iii) the promotion of SuDS solutions. The law calls to the Ministry of Environment to establish national guidelines to define environmental objectives and technical guidelines to design specific measures and manage stormwater, as well as the promotion of integrated urban drainage planning and CSO monitoring. The guidelines are still in preparation.

In 2016, a new modification of the Spanish regulations for the public sector, which introduces urban risk management, states that new industrial and urban developments must introduce SuDS, such as permeable surfaces, to reduce the risk of flooding. The law introduces the principle of hydrological invariance, and it establishes a situation where SuDS are compulsory within the country. In addition, the Instruction for Hydrological Planning emphasizes the need to consider and evaluate diffuse and point pollution sources. This text specifically considers pollution sources from combined and separate stormwater overflows in urban areas, industrial estates, or roads (Ministerio para la Transición Ecológica, 2019; Andrés-Doménech, 2021). This national framework provides general rules for regional and local governments to develop their own regulations. The territorial organization of the country leads to different views and scopes with regard to facing the problems which are out of the scope of this analysis.

2.4.3. Putting the Co-UDlabs project into perspective

Many of subjects covered by Co-UDlabs are directly in line with the heterogeneous Spanish framework on urban water governance and current and upcoming regulations reviewed. At the highest hierarchy level, an integral approach for urban water management is expressed, but the required urban drainage components and their interfaces with wastewater treatment and drinking water supply are not yet fully developed. This way, Co-UDlabs can support to overcome the water challenges with different actors from the water sectors such as scientists, local and national authorities and practitioners.

[9] "Communities of users" is a direct translation describing a legal figure contained in the water act. When several municipalities join to provide sanitation or water supply services, they are legally constituted in this form.

In Spain, **national guidelines** for the design and operation-maintenance of several urban drainage assets are still missing. Some examples are related with the integral approach to design urban water systems considering flooding (to a lesser extent) and pollution loads in rainy events. Specific regulations for CSO tank sizing or SuDS design are under development. Furthermore, the need of monitoring and data acquisition is also a fundamental issue under debate. Some of the experimental facilities and, especially, some of the planned activities in the networking and Joint Research Activities can fit into this topic.

Natured-based solutions and blue-green infrastructures are also a topic which appears in almost all the regulations and Spanish vision documents. Some of the facilities of Co-UDlabs are specifically related to the monitoring and implementation of new sustainable solutions, as well as the work developed under Joint Research Activity 3.

The **analysis of the costs of maintenance and rehabilitation of buried assets** (pipes) in drainage systems is a recurring topic in Spain, but it has not been promoted nor developed by water authorities and practitioners in depth yet. Prior to the implementation of a taxation policy that allows financial sustainability of the urban drainage assets, a best knowledge of the system (monitoring techniques) and assets rehabilitation (technology approaches) is needed. The analysis of assets deterioration is the core topic of Co-UDlabs Joint Research Activity 2.

The transfer of the results obtained in Co-UDlabs research infrastructures into real-world urban sewerage and drainage systems is one of the great challenges of Co-UDlabs. The Transnational Access Program aims to create multi-sectoral teams involving academia, operators, industry and policy makers to facilitate this transfer. The technological and knowledge transfer must be done at various levels, involving and training actors external to drainage systems, such as politicians, technicians, and citizens. This last aspect should be better considered in the project's networking activities.

2.5. Switzerland: fragmented roadmapping

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2.5.1. National context

In the 1950s, the water quality of many lakes and rivers was not apt for human use or recreational activities. Thanks to targeted investments in the past, Switzerland today has a nationwide, safe and efficient wastewater disposal with high-quality services, which makes water quality today among the best in Europe. It is now a matter of strategic and tactical decisions to provide the available resources in the long term and to use them efficiently to maintain and improve services. For Co-UDlabs, common topics include new guidelines for hydraulic assessment of urban drainage systems, or safeguarding the quality of water bodies. Other needs are not yet considered in Co-UDlabs, or lie outside of its scope, such as how to best use Blue-Green Infrastructures (BGI) to cool cities and improve urban biodiversity or to how to improve organizational and policy aspect of stormwater management.

Historically, the protection of water bodies in Switzerland started with a protection against fluvial flooding (1850-1888). Qualitative Water protection and political activism (1950-1972) led to widespread construction of urban drainage systems and wastewater treatment plants (WWTPs) for the treatment of polluted wastewater from households and industrial and commercial enterprises. As the legislation is generally water quality-impact oriented (“immissionsorientiert”), a subsequent phase of quantitative water protection and monitoring (1972-2000) lead to a more holistic version of the Water Protection Act and Water Protection Ordinance (“Gewässerschutzgesetz” (GSchG) and “Gewässerschutzverordnung”), which now also included hydropower use and agriculture and sets specific goals to remove nutrients (carbon, phosphorus and nitrogen) and other, mainly biodegradable pollutants. In this phase, the effectiveness of the WWTPs was improved by the widespread construction of combined sewer overflow tanks. To further improve stormwater management, the measure of a general urban drainage plan (GDP) was introduced. The GDP is a planning instrument for the strategic development of urban drainage infrastructure, which includes different modules such as flood protection, infiltration/inflow, condition assessment and investment planning.

In 1986, the Federal Council enforced a definitive ban on phosphates in textile detergents. This was an important milestone, because in Switzerland it is considered very important to control pollutants at the source, which is usually more effective than end-of-pipe control strategies. Regarding stormwater pollution, source control in Switzerland is implemented in a similar fashion to remove pollutants from road drainage, as well as heavy metals and pesticides in runoff from "building envelopes", such as copper roofs and impregnated facades.

More recent legislative developments concern the revitalization of water bodies (2006), which considers securing space, revitalization, hydropower (ecosystem, flood protection, utilization). Most recently, the elimination of wastewater-borne micropollutants in WWTPs was included in the Water Protection Act (2016). Currently, approx. 100 selected wastewater treatment plants are to be retrofitted with an additional treatment stage, ozonation or filtration with granulated active carbon. However, stormwater-born pollutants are not considered and it is currently being debated how to best design and operate such advanced treatment for wet weather flows.

Important Actors

Federal office of the environment (BAFU): According to Swiss law, the federal government must define the requirements for water quality. The GSchG also specifies the locations where the wastewater must be disposed of and treated (Articles 10 and 11). Interestingly, the cantons are responsible that municipalities develop their GDP and corresponding Regional Drainage Plans (RDPs) for larger interconnected systems (Article 7). The federal government may also approve subsidies, e.g., for the upgrading of WWTPs to eliminate micropollutants or nitrogen.

Cantonal environmental regulators: As Switzerland is rather fragmented (the canton of Appenzell Innerrhoden has 16,145 inhabitants and 46% of the 26 cantons have less than 200,000 inhabitants) environmental regulatory authorities not only ensure the environmentally sound disposal of wastewater and solid waste, but also organize other tasks, such as the supply of clean drinking water, and protection against flooding. This also means that water issues are dealt with in a varying number of different cantonal laws and ordinances. The responsibilities for the execution of the individual tasks (e.g., canton or municipality) are also regulated differently from one canton to the next.

Swiss association for wastewater professionals (VSA): The Swiss association for wastewater professionals ("Verband Schweizerischer Abwasser- und Gewässerschutzfachleute") aims at the sustainable development of water management and the promotion of integral protection of water bodies. It promotes the exchange and cooperation of all experts working in these fields, and is involved in professional education and training as well as in the promotion of young professionals. The VSA contributes to the harmonization of water protection throughout Switzerland with guidelines, recommendations and fact sheets. The VSA aims to achieve its goals through measures such as: i) promotion and further development of the focal points in general, technical, scientific, economic, legal, organizational and social matters and social issues, ii) publication and further development of rules and regulations, association and industry publications, and inspection and testing procedures, iii) implementation of professional training and continuing education programs, incl. higher vocational training, iv) cultivation of the exchange of experience and opinions and organization of professional events, v) collaboration with related organizations in Switzerland and abroad, iv) promotion of research and development, vi) communication and public relations with politics, economy and society.

Wastewater utilities: In Switzerland, urban water management is mostly organized by so-called Zweckverbände, wastewater associations. Their goal is to collect and treat the domestic, commercial and industrial wastewater produced in the catchment area of the association. Typically, the associations operate a central wastewater treatment plant on behalf of several municipalities. Often, they operate the main collectors as well, sometimes also special structures, such as pumping stations or CSO tanks. However, the latter can also be operated by the municipalities.

Other actors concern associations involved in research and development (Universities, Universities of applied sciences, Eawag) or infrastructure management ("Kommunale Infrastruktur"). As stormwater management has a lot of interfaces to other disciplines, there are many other actors from related disciplines, such as agriculture, roads and traffic or meteorology and hydrology, which cannot be described here.

2.5.2. Guidelines and lines of action

An integrated national strategy for urban stormwater management is still lacking in Switzerland. However, we identified three major studies, which provide detailed suggestions to address current and future challenges. The first is a synthesis report "Wastewater Management 2025" (Eawag, 2012), the second focuses on heat in cities (BAFU, 2018), and the third addresses extreme precipitation and stormwater management in climate-adapted cities (BAFU, 2022). The latter is going to be published later in 2022 and is probably most relevant for the Co-UDlabs project.

Wastewater Management 2025 ("Abwasserentsorgung 2025")

The synthesis report "Wastewater Management 2025" contains seven module reports and one "recommendations for actions" chapter. The module reports were prepared under the aegis of Eawag experts together with relevant stakeholders from the Swiss urban water management sector. It has the following "recommendations for action":

1) **Leading infrastructures into the future:** Specific measures are recommended that aim at improving infrastructure management by reducing the heterogeneity and organizational fragmentation in the management of private as well as public sewer infrastructure. Main actors are the cantons and VSA, but also the federal government.
2) **Integrated catchment management:** Contains measures that improve and promote coordinated action in urban water catchments. None of the measures have the highest priority and most have been rated with a medium importance. For all measures the federal government can be identified as an important actor to coordinate the various stakeholders.
3) **Optimize urban drainage:** Includes measures that guarantee the safe and optimal drainage of storm- and wastewater from the settlement area. Measures should mainly be carried out by VSA, which should elaborate professional standards and guidelines for the hydraulic assessment of sewers or the integrated assessment of sewers, WWTPs and receiving waters. Both are currently being developed (see below).
4) **Use synergies and harmonize procedures:** Contains measures that should be taken supra-regionally or at the national level to create synergies. Again, the professional associations and the federal government are identified here as national actors. Many of the measures in this field of action have been partially implemented, such as common geodata standards and performance indicators, but still require action. Overall, the effort to trigger individual measures in this field of action is small - even if the total effort of the individual measures is estimated to be high in some cases.
5) **Safeguarding water quality:** Includes measures that directly benefit or improve the water quality of surface or groundwater, such as better understanding the impact of wastewater exfiltration on water bodies. The federal government and research are the main actors involved.

Heat in cities

Regarding heat in cities, the study emphasizes that climate change will lead to more frequent and longer periods of hot weather. It concludes that urban planning can reduce this urban heat island effect by adapting the design of outside space. Open green spaces must be planned with plenty of shade, and cooling water elements accessible to all. Not only water is important for cooling, but also supply with fresh air from the surrounding area and air circulation in the city.

Urban Stormwater Management

Regarding extreme precipitation in climate-adapted settlements, the study emphasizes the potential of the "sponge city concept", which has demonstrated its effectiveness internationally in large cities in Asia, the Americas and Europe, including Switzerland.

It is concluded that an important factor for success is the transdisciplinary cooperation of the different actors. This means that those responsible for urban drainage, for flood protection, experts from the fields of urban planning and development, architecture and landscape planning, building owners, political actors, etc. must all work together to develop and implement solutions.

Specifically, regarding the current legal basis, the report concludes that the current instruments already allow for a good handling of stormwater in principle:

- A legal opinion in the canton of Vaud provides clarification on the handling of surface runoff.
- Federal subsidies for measures to protect against surface runoff are already possible under the current Hydraulic Engineering Act ("Wasserbaugesetz"), but have rarely been used to date. Spatial planning measures that regulate the handling of natural hazards should now also be eligible for subsidies.
- The VSA "Stormwater guideline" ("Regenwasserichtlinie") considers the prevention of runoff as top priority. This supersedes the current strategy that unpolluted stormwater should to be infiltrated.
- The building and wastewater regulations of various cities and municipalities already require runoff-reducing measures such as green roofs, and in some cases grant financial incentives for this purpose.

Two important elements that are not yet implemented in Switzerland, but already standard in other countries, such as Germany, are:

- Prioritizing stormwater retention and evaporation over infiltration;
- Tiered, risk-based handling of heavy precipitation with use of structural features on the surface for (temporary) retention and damage-free routing of overland flows, e.g. to (water)parks and multifunctional sporting grounds.

The study sees various current efforts to incorporate these concepts into the legal bases and instruments:

- The Federal Hydraulic Engineering Act is currently being revised, integrating surface runoff and risk-based spatial planning.
- According to the "Action plan for Adaptation to Climate Change" (Schweizerische Eidgenossenschaft, 2020), the guideline for spatial planning of the Federal Office of Regional Planning (ARE) will include a fact sheet on climate. This offers the opportunity to include sustainable stormwater management.
- Various cantons are now including incentive systems for decentralized stormwater management in the revision of their urban drainage and wastewater fees.

Further related guidelines and technical recommendations

To translate these high-level conceptual studies into actionable information and standards, VSA and other professional associations are currently developing several guidelines or recommendations.

The recommendation "**Hydraulic assessment of sewer systems**" aims to implement the principles of EN 752 in Swiss drainage planning. This introduces risk-based methodology to handle extreme precipitation and surface runoff. Among other things, this should close the conceptual gap that currently exists between fluvial (return period of 100-300 years) and pluvial (return period of 10-30 years) flood protection. These aspects will also be incorporated into the "GDP handbook", which will be updated by 2023.

In this 3-year project, the VSA aims at promoting the integral use of stormwater in the urban environment. Specifically, this **Sponge City initiative** aims at summarizing the available know-how in the form of "best practice" examples and provide the municipalities with concrete instructions on how to proceed in a structured and holistic manner. In addition, the VSA would like to ensure the exchange of knowledge and coordination regarding climate-adapted water management, integrate the "sponge city" aspects in the General Drainage Planning (GDP) and ensure that the new requirements are not only known to the municipalities, but also to a broad professional audience.

In recent years, advances in ICT technology, such as remote data transmission and control, affordable and robust SCADA systems, etc., cost for remote monitoring and surveillance and storage space open up new possibilities to improve receiving water protection through the **integrated management of the overall wastewater system** (BAFU, 2022).

Recommendation to define the state of the art in maximizing the performance of our current urban drainage and wastewater treatment infrastructures: The future guideline is structuring and standardizing the steps that have to be taken to optimally operate the wastewater infrastructure. It will not promote specific modelling tools. An important novelty will concern recommended performance metrics for combined sewer overflows, e.g., days with overflow or hours with overflow per year.

For the sewer network, the guideline focuses on special structures, such as pumping stations and combined sewer overflows. For the WWTP, the focus is on the hydraulic capacity, and for the water bodies, a focus is on considering the specific sensitivity of all water bodies in the drainage general drainage planning. The envisioned publication date is summer 2023.

To maintain the functionality and value of the drainage infrastructure for optimal water protection economically and efficiently, the VSA is also revising the guideline for "**quality control in the rehabilitation of sewers**" (QUIK) ("Qualitätssicherung in der Kanalsanierung"). A focus is on the procedure, test and certifying institutions for quality assurance in renovation and repair procedures of underground sewer systems. This establishes and guarantees the basis for high-quality construction techniques, construction materials and rehabilitation methods.

The revision of other standards and guidelines is also planned, e.g., VSA/suissetec SN 592 000 on Property drainage or The Swiss Society of Engineers and Architects (SIA) SIA 312 Green roofs.

In summary, to date there are various initiatives to adapt the urban drainage infrastructures to climate change. In Switzerland, a hotter future will result in more variable and probably more intense precipitation. For Co-UDlabs, a very important issue is probably the international knowledge transfer of concepts, which are successful in other countries, e.g., how to systematically coordinate land use planning and stormwater planning with appropriate spatial planning instruments.

2.5.3. Putting the Co-UDlabs project into perspective

Many of the issues formulated in guidance documents, guidelines and recommendations for stormwater management in Switzerland are in line with the issues identified in Co-UDLabs and associated goals.

All agree that the following topics are very important:

- **Pluvial flooding:** In Switzerland, pluvial flooding is a very important problem, which will most probably become more severe with increasing climate change. Already today, approximately two thirds of buildings in Switzerland are potentially affected by surface runoff. Approx. half of these are assigned to the hazard-free, i.e., white, hazard area in the flood hazard maps. On average, floods cause damage of around 270 million Swiss francs per year. Surface runoff accounts for approx. half of the claims and more than a quarter of the total damage. Current topics are hydrodynamic modeling, monitoring and provision of adequate (synthetic) rainfall information for risk-based drainage planning in the current and future climate.
- **Optimizing the use of current infrastructure:** As monitoring data from urban drainage systems are becoming more and more implemented/available, utilities also strive to use these data in maximizing the use of the existing infrastructure. Needs concern implementation and performance assessment of real-time control systems, robust solutions for pollution monitoring and data quality control.
- **Sustainable urban drainage, blue-green infrastructure (BGI), sponge cities:** Several actors in Switzerland are promoting concepts of BGIs. While the technologies, such as green roofs, are widely available and generally accepted, further education is needed to optimally integrate them into the planning process. Further topics concern the operation and maintenance of such infrastructures and common accounting standards to finance these measures.

- **Digital transformation of urban wastewater management:** The VSA has recognized the importance of digital transformation rather early, and has developed a data model (VSA-DSS) for digital processing of important GIS and topological data, such as land use, network infrastructure, pipe material, etc., (REF_DSS). However, harmonization of data, interfaces for data exchange and common data platforms is still ongoing. An important issue is the transition from a planning-based regulation of urban drainage systems to a performance-based regulation similar to those of WWTPs.
- **Further education and capacity building:** Further education is needed for specialists from engineering or environmental consultancies, industry, administration, and non-governmental organisations to translate scientific knowledge into practice. In addition, up-to-date knowledge has to be integrated into existing standards and common interpretations of regulations as well as workflows and tools have to be developed. In Switzerland, most education activities are organized by the VSA. Special courses on emerging topics are also organized by Eawag and Universities of applied sciences to promote exchange among participants and between science and practice.

However, some of the needs regarding stormwater management in Switzerland are not (yet) considered by Co-UDLabs or go beyond its scope:

- **Assessment of micropollutants:** In Switzerland, the regulation of micropollutants is a current topic, also the integrated assessment of sewers, WWTPs and water bodies. A very important point is the definition of key performance indicators of sewer systems (and WWTPs) based on (uncertain and systematically biased) monitoring data. Also, if we expect “intelligent” BGI in the future. How could monitoring data be used to better manage the entire wastewater system?
- **Organizational and policy aspects:** As urban water management in Switzerland is very fragmented, organizational aspects and how the individual actors in utilities and municipalities collaborate is also considered very important. Although organizational aspects are largely lacking in Co-UDlabs, this most probably requires social and political science skills, which is probably asking too much of the current consortium.
- **Using stormwater for cooling:** Regarding adaptation to climate change, a very strong topic is using stormwater to cool cities. While Co-UDlabs is also working with green roofs and associated water balances, e.g., evaporation which is also important to lower temperatures, this aspect could receive more attention in Co-UDlabs.
- **Stormwater and biodiversity**: Also, an important topic in Switzerland which is not considered in Co-UDlabs is how BGI can have a positive impact on urban biodiversity, e.g., by creating green corridors in urban areas.

2.6. The Netherlands: the 2022-2027 National Action Program Water

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2.6.1. National context

The Netherlands has a long history of water management (waterboards claim to be some of the first democratic public organizations, dating back to 1255 AC). Initially these organizations had a very limited service area, resulting in a large number of institutions (e.g., in 1952 there were still 2500 waterboards, at present there are 21 left).

Until 1970, the focus of the waterboards was related to water quantity with a strong emphasis on agricultural/economical interest. However, with the introduction of the Dutch Water Pollution Act in 1970, a second type of waterboards was introduced, the so-called Zuiveringsschappen. These public entities had the task to reduce the load of oxygen-consuming pollutant discharges from sewer systems. In the early 1980s, a reorganization started in which the existing waterboards and the Zuiveringsschappen merged into so-called ‘over-all waterboards’ responsible for regional waterbodies. In parallel, Rijkswaterstaat (the national directorate for public works and water management) had the responsibility for the water quantity and quality of the Dutch rivers, canals and large waterbodies (like the Ijsselmeer).

In the mid-80s, a new concept was adopted for the integrated management of large water systems (in the Netherlands, these are mainly the Rhine River and the North Sea). As result of the international Rhine Committee action plan (1985-1995), efforts were directed to reduce the emission of a series of selected pollutants from diffuse sources by 50%. This involved a series of research projects specifically aiming at the reduction of discharges from urban drainage systems, the so-called NWRW program (NWRW, 1989). This research program resulted in a first estimate on the amounts of pollutions discharged from (mostly) CSOs and to a lesser extent the emission from stormwater systems. Additionally, guidelines from the EU were implemented, putting limits to the emission of nutrients (nitrogen and phosphorus). New features in a national policy were (i) the local and temporal scale on which it was applied, and (ii) the notion that for vulnerable locations (from an ecological point of view) tailor made solutions were needed. In this period, municipalities received the responsibility to draft detailed plans for their urban drainage systems that had to be produced in close cooperation with the waterboard(s). These plans encompassed a detailed description of the systems present, the technical state they were in, a detailed description of the hydraulic (flooding) and environmental (discharges into surface waters and/or groundwater bodies) conditions along with plans to improve the systems, and the financial consequences of these plans. These urban drainage plans were drafted for a 4-year period, although in some cases 10-year plans were adopted. In parallel, an important guideline (Leidraad riolering, 2004; van Mameren and Clemens, 1997; van Luijtelaar and van Rebergen, 1997) was adopted with respect to the quantification of urban drainage hydrodynamic behaviour. The application of hydrodynamic models was specified to a certain extent, as well as the manner in which the results should be reported. This approach was chosen in favour of specifying a software product so as to encourage the further development of the models applied. By the end of the 1990s, many municipalities widened the scope of the plans, also incorporating the interaction of groundwater and groundwater management with their urban drainage systems. This led to a very close co-operation between municipalities, water boards and Rijkswaterstaat.

In terms of urban drainage research, there was a double focus: on one hand measuring systems were implemented in order to validate/calibrate the hydrodynamic models applied in the municipal urban drainage plans, on the other hand the complexity of the so-called integral water-management approach was a very important subject in countless research projects.

The EU WFD aims for a good ecological and chemical status of waterbodies along with special demands for Natura 2000 areas. Given the national developments as described above, the organization and the co-operation between the involved parties was a good starting point. Nevertheless, the implementation was by no means easy, as member states had the liberty to choose the desired quality level for individual waterbodies. This materialized in a series of objectives for water quality in the Netherlands that should be realized by 2027. According to the latest progress report, it is expected that national waterbodies (large rivers etc.) will comply with the demands by 2027, while for regional waterbodies it is expected that only 35-65% of them will comply with then. The main reason for this is that for the national waterbodies less strict demands were formulated due to the appreciation of the general use of these waters (mainly the economic value is an important issue taken into consideration here).

Another important driver for policymaking is the notion of sustainability, which is taken in a very broad sense: e.g. when a municipality plans for new developments, it needs to choose a system for urban drainage that enables

- the reuse of water,
- to keep various 'streams' separated resulting in the choice of separate sewer systems, unless they are financially or economically not feasible,
- to keep stormwater 'on site' to avoid local drought and subsidence.

This has called for research activities in the field of wastewater systems; e.g. anaerobic digestion to enable energy production, reclamation of N and P, but also studies into the transportability of so-called domestic slurries. The latter implies a reduction of water consumption and results in an increased efficiency of energy production and N and P retrieval. Additionally, experimental work has been performed on systems that enhance infiltration of stormwater into groundwater bodies.

A very important development is that asset management of urban drainage systems has gained more attention over the past 30 years. Regular inspections, rehabilitation and replacement plans are drafted on a regular basis by municipalities. Asset Management has drawn the attention of researchers only in the past 10-15 years mainly aiming at getting the right information from the available data and to a lesser extent, attention has been paid to the development of (monitoring) methods in the broadest sense of the word. At present, the main concern in the medium and long term is climate change, because a considerable portion of the Netherlands has a subsea level, making flooding the main issue with respect to high water protection from rivers and the sea. With respect to urban drainage, the concerns are focused on how to deal with the expected (and to a certain extent already occurring) increase in rain intensities and long periods of water shortage. Waterboards draft long-term plans on how to cope with these threats. On a national level (concept National Water Program 2022-2027 cNWP (cNWP, 2022)), the three main long-term goals for deltas are to (i) make them safe and climate proof (ii) in a sustainable way, which also (iii) allows for economic activities.

National authorities, waterboards and municipalities need to co-operate to achieve this and work out plans on a detailed level. In the cNWP, the need for knowledge development is identified as crucial prerequisite to achieve these goals. With a new legislation (omgevingswet[10]) in which the responsibilities are given to local authorities to enable tailor-made solutions, a range of questions arises:

- How can we ensure long-term sustainability?
- How can we maintain certain functional standards?
- How can local knowledge and local conditions be considered optimally?
- Do we have enough knowledge on the interaction between the relevant sub-systems (urban drainage systems, surface waters, groundwater bodies) in terms of water quantity and quality dynamics?

Since the responsibilities are given to the local authorities, the national authorities formulated a framework on a high abstraction level for further development only.

2.6.2. Guidelines and lines of action

In the cNWP for 2027, the following ambitions are formulated:

- The European Framework Directive measures are completed.
- Measures as formulated in the groundwater guidelines are completed.
- Freshwater measures phase 2 contributing to a climate-proof and water-robust design of the Netherlands are implemented.
- A new North Sea program (2028-2034) including a new Marine Strategic plan part 3 (update) is drafted.
- River basin management plans (2028-2034) related to the EU WFD are formulated
- New flood risk management plans (2028-2034) are formulated

The national authorities will draft a research program into the monitoring of **climate change** and the implications for all relevant sectors (including urban areas). This research plan is expected to be available in the course of 2022. Much attention will be paid to climate change in relation for flood defenses (sea, rivers), along with urban areas and their specific characteristics.

[10] https://www.rijksoverheid.nl/onderwerpen/omgevingswet

With the expected increase in peak intensities with climate change, simply increasing the capacity of existing systems will not ensure sufficient flood protection or acceptable environmental protection levels in the broadest sense. This implies that other measures, e.g., urban-territorial planning, design of houses and infrastructure, and alternative ways of stormwater management need to be considered, requiring a significant research effort on **climate adaptation** in the coming years.

The presence of pharmaceutical residues and other **emerging substances** (e.g., PFAS, microplastics) in the aquatic environment is of growing concern. The medical, industrial and water sector are expected to jointly find ways to reduce and **control the emissions and remove these substances**, which requires monitoring of these substances to provide a data basis for such measures. There is a growing concern about meeting water quality goals in a general sense.

Improving the **ecological quality of waterbodies** as requested by the EU WFD, implies a further reduction of discharge of nutrients from sewer networks with a mixture of source control, end-of pipe solutions, and separation of different qualities of water (black, yellow, grey). This may lead to alternative sanitation combined with advanced wastewater treatment methods. In addition to the impact of new design and maintenance on the waterbodies in the urban environment, this will influence urban planning and the quality of living as well. In the course of the past 10-15 years, a lot of research has been conducted into these subjects, however the translation into engineering guidelines and design methods is still largely missing.

All authorities (on a national and province level, waterboards, municipalities) have a **responsibility** to ensure a safe, healthy and sustainable water system. Given the hydrological situation of the Netherlands in Europe, tuning policymaking and implementation of policies with other European countries (specifically Belgium and Germany) are crucial. The co-operation between these entities needs monitoring for which a rather complex system of **legislation, policymaking, asset management plans, detailed action plans and long-term agendas** are drafted (cNWP, 2022).

2.6.3. Putting the Co-UDlabs project into perspective

The subjects covered by Co-UDlabs are directly in line with the ambitions formulated in the cNPW with respect to urban drainage. As the cNWP advocates an integral approach across water systems, organizations and sectors, it is not very specific about water management in urban areas; nevertheless, it is easily seen that Co-UDlabs can supply important input for local authorities and practitioners.

Guidelines on asset management for SUDS need to be developed, and to a lesser extent such on design. Also, the need for monitoring these systems is growing as the long-term behavior is known to be relatively unpredictable and not understood in every detail. A similar situation exists with respect to the **design and construction of sustainable wastewater systems**. Laboratory research along with (semi)industrial-scale experiments have provided knowledge that needs to be translated into design guidelines. The experimental facilities offered in Co-UDlabs perfectly match this need.

To **improve scientific knowledge**, the cNWP implies a need for increasing monitoring data from a wide spectrum (from data on climate change to the presence of micro-pollutants), along with a description how to ensure data quality. WP 6 seems to be (partially) fulfilling this need. Another need is to work on SUDS and their design, management and performance. The experimental Co-UDlabs facilities offer this option as well. Overall, an improved understanding of processes occurring in UD systems is beneficial with respect to all activities related to their asset management. Co-UDlabs is a powerful vehicle to contribute to this.

Readily available results from scientific research with respect to sustainable wastewater systems (energy production, reclaiming raw materials), urban planning, application of monitoring data and model results **need to be translated into design methods and guidelines** that have to be communicated to practitioners and should be incorporated in the educational system. The Co-UDlabs project will contribute to that goal through, amongst others, webinars and the YouTube channel. A translation into Dutch will be needed in most cases though.

2.7. United Kingdom: road mapping up to 2050

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2.7.1. National context

The UK water sector is fragmented with a range of organizations with different responsibilities in terms of the provision of effective drainage, treatment of wastewater, and the protection of the environment. In the UK, water supply and wastewater activities are organized by a small number of catchment-based water and sewerage companies (WaSCs). They are responsible for supplying water that is potable, collecting and treating wastewater, and also providing "effective" drainage. These responsibilities were previously carried out by Regional Water Authorities, public bodies under democratic control, but in the early 1990s the UK government decided to privatize these bodies and to issue 25-year licenses to private companies for water supply, wastewater collection and treatment and effective drainage within a designated river basin catchment. The underlying reason for this change was that the government recognized that the UK had under-invested in water related infrastructure for decades and it did not want taxpayers to fund urgently needed investment. The government decided to create private companies that could raise investment funds from the financial markets based on using the existing assets. Currently it is estimated that the nine largest UK water companies have over £50Bn debt that has funded infrastructure investment since privatization. The government recognized that they were forming private companies (with shareholders) that were effectively regional monopolies of an essential service so created a framework of strict regulation.

There are three regulators; the Drinking Water Inspectorate[11], who regulates the quality of drinking water, the Water Services Regulation Authority (OFWAT)[12], and the Environment Agency (EA)[13]. The last two regulators significantly influence the management of urban drainage systems. OFWAT's purpose is to ensure water company shareholders get a fair return on their investment and that customer charges are controlled. OFWAT requires WaSCs to agree a 5-year Asset Management Plan (AMP) that outlines their investment and operational obligation that are funded by an agreed price to consumers.

In the UK, tax payers do not fund any water and wastewater services. OFWAT benchmarks companies against each other so that customer charges are "value for money". The EA is the environmental regulator and has a duty to ensure that water companies do not cause significant impact on the natural environment. The EA regulates the management of intermittent storm overflows and pollution of groundwater sources. The EA also has a role in managing river flood risk – which complicates the management of flood risk from urban drainage systems. All three regulators are overseen by the UK government minister in charge of the Department of Food and Rural Affairs (DEFRA). DEFRA has a political role but does not regulate individual WaSCs. Normally DEFRA is not pro-active, but in the last few years it has intervened directly in terms of requiring the event duration monitoring of practically all storm overflows and has strongly indicated that there will be much stricter control of pollution impacts of urban drainage systems on the UK's receiving waters. This has been indicated by the formation of a national storm overflow task force and the recently enacted Environment Act (2021)[14], which places significant new obligations on water companies in the field of urban drainage.

This system of private WaSCs only applies in England, there are different regulatory and political structures in Scotland, Wales and Northern Ireland.

[11] https://www.dwi.gov.uk/
[12] https://www.ofwat.gov.uk/
[13] https://www.gov.uk/government/organisations/environment-agency
[14] https://www.legislation.gov.uk/ukpga/2021/30/contents/enacted

This structure has resulted in a number of non-governmental organisations that interact with the WaSCs. WaterUK[15] is a trade organization that represents the interests of the WaSCs, UK Water Industry Research[16] (UKWIR) is a subscription R&D organization that is funded by the water companies to conduct near-term research. There is also the Consumer Council for Water[17], a statutory organization that is supposed to represent the interests of consumers in the UK water sector.

To add to this complexity, local authorities have a responsibility to investigate flooding incidents and manage flooding in urban areas, which overlaps with responsibilities of the WaSCs to adequately drain their service area, and the EA to manage flood risk of the main rivers. Therefore, in the area of managing flood risk there are a number of potentially overlapping responsibilities and organizations (with different systems and cultures), that have traditionally hampered collaborative working.

2.7.2. Guidelines and lines of action

In the UK, the complexity has led to a number of initiatives from different parties to develop roadmaps that do not have statutory backing. Firstly, in this report, three initiatives will be considered: one from UK Water Industry Research (UKWIR), one from UK-Water on Wastewater and Drainage Management Plans and one from a group set up by the UK's Government's Department of Environment, Food and Rural Affairs (DEFRA), but with broad representation from Water Utilities, Suppliers, Academia and regulators, the Storm Sewer Overflow Taskforce focused on intermittent discharges from overflows.

In 2019 UKWIR started a "Big Question" program. This was a series of roadmapping projects that examined the 12 big questions facing the UK water sector. These "big question" projects involved strong engagement with different players and structured assessment of the different pressures that may emerge over a timescale up to 2050. UKWIR roadmapping projects developed a program of potential R&D projects structured in terms of short-, medium- and long-term needs. The results of both these projects, BQ5: "Delivering an environmentally sustainable wastewater service by 2050", and BQ6: "Zero uncontrolled discharges from sewers by 2050" were used to identify the needs listed in Table A.1.

Over the last decade, there has been a strong drive in the UK to promote more collaborative working between organizations in the field of urban drainage. This aspiration has been driven by two factors, the first is the currently fragmented legal and regulatory water management structure in the UK, and the second is the growing body of evidence that collaborative working practices can deliver significant benefits to many parties. There has been the growing lack of public trust in UK WaSCs has led to demands for legislation to obligate collaborate work and higher levels of transparency to ensure it is implemented.

Drainage and Wastewater Management Plans (DWMPs) are now a legal requirement under the recently enacted Environment Act (2021). They aim to provide more consistent, long-term planning, to address key risks and make urban drainage and wastewater systems more resilient. DWMPs utilize three groups of tools: (1) capacity assessment frameworks, (2) storm overflow assessment frameworks, and (3) wastewater resilience metrics, to better structure wastewater and drainage planning. All these frameworks and associated tools and documentation are available from Water UK's website[18]. DWMPs should cover a minimum of 25 years and involve a wide range of stakeholders, not just utilities and their customers. These plans consider all drainage assets within an area, prioritize risk in a transparent way and then attempt to balance competing needs against available resources. Given their long-term and collaborative nature it is hoped that they will deliver more innovation.

In the last 4 years, intermittent overflows into receiving water bodies in the UK have received more public attention. This is caused in part by more public transparency with asset performance data. In 2013 the government required

[15] https://www.water.org.uk/
[16] https://ukwir.org/
[17] https://www.ccwater.org.uk/
[18] https://www.water.org.uk/policy-topics/managing-sewage-and-drainage/drainage-and-wastewater-management-plans/

all WaSCs to progressively install event duration monitoring on the vast majority of the UK's storm sewer overflows and publish the data. This open data has generated significant public concern and the Storm Overflow Taskforce was set up by DEFRA in 2021 to examine how intermittent sewer overflows may be better managed. This is a current political imperative in the UK and a draft Storm Sewer Reduction Program has emerged – primarily to reduce water quality impacts and public health impacts in recreational waters. The recent Environment Act (2021) forces WaSCs to agree spill reduction targets with government and also install upstream and downstream water quality monitoring on all storm sewer overflows operated by WaSCs. The implementation timescale is by the mid-2030s.

2.7.3. Putting the Co-UDlabs project into perspective

The recent legislation to quantify impact on the natural environment and the desire to boast collaborative working and be more open as regards data links well with Co-UDlabs.

- Open data and sensors, in the UK WaSCs will be expected to monitor asset performance and make any monitoring data open to the public, often in near real time. This aligns with Co-UDlabs work on sensor development and data validation.
- Pollution release into the environment, whilst a major focus currently on limiting the impacts of storm sewer overflows, this assessment of impact will also require better knowledge of pollution transport and transformation processes. This area of investigation links well with the joint research activities and some of the TA facilities.
- Underlying the UK water industry is the concept of periodic regulatory assessment, in 5-year AMP planning periods. This continually requires better methods of asset assessment, lower carbon emissions in order to meet the evolving needs of WaSCs to demonstrate to the economic regulator OFWAT that companies are being run efficiently both for their customers and shareholders.

Urban drainage in the UK is structured in a fragmented way with a range of public and private bodies having obligations and duties to reduce flood risk and protect the environment. There has been a drive to better integrate efforts, via organizational collaboration and new data-based technologies. Recently central government has been more prescriptive with regards to fixed targets, their intervention has been driven by more publicly available asset performance data.

2.8. Summary of national roadmaps

The organisation and legislative structure of stormwater management and treatment in the seven countries represented in Co-UDlabs is quite different due to historical development, climatic and geographical conditions as well as economic situation, resulting also in different degrees of private/public involvement. The way national regulations and frameworks have to be detailed and implemented results on a local level also in different degrees of competences and forms of interdependences. In Denmark and the Netherlands, the general responsibilities seem to be well defined between the different actors on the national, regional and local level, whereas the situation in the other five countries is more complex. Especially the management of stormwater and the implementation of SUDS is not always clearly defined. Overlapping responsibilities between municipalities, specific catchment-based organisations (Germany, Switzerland, England, Spain) or municipal clusters (France) and/or undefined allocation of competences lead to conflicts or neglecting these tasks. Varying legislation in the administrative divisions (e.g., the 16 states in Germany, 17 autonomous communities and 2 autonomous cities in Spain, 26 cantons in Switzerland, or the four countries of the United Kingdom) adds to the overall complexity.

However, there is an awareness of a necessary change towards sustainable development in the water sector in all countries, although the implementation into the legal framework remains on different levels and is not always clearly defined:

- Denmark and Spain: national action plans oriented around the SDGs formulate strategic objectives
- The Netherlands: draft National Water Program 2022-2027 defines integral long-term goals for the deltas

- Germany and France: recognition of the role of land use in future stormwater management; while already implemented into a law in France (NOTRe), currently as draft National Water Strategy in Germany
- France and United Kingdom: plans specifically dedicated to sustainable stormwater management and overflow reduction (Action Plan 2022-2024 in France/Storm Sewer Reduction Program in UK)
- Switzerland: integral national strategy still missing, but the three described reports on wastewater management, heat in cities and extreme events/stormwater management point into the direction such a strategy could take

3. The consultation for the revision of the EU UWWTD

The public consultation for a revision of the Urban Wastewater Treatment Directive (UWWTD) is another public source, which allowed not only experts but also any citizen of the European Union and associated countries to express his or her opinion on the requirements for a more sustainable management of stormwater, and other topics related to water pollution and wastewater treatment. In 2018, a first consultation was conducted with the aim of gathering the opinion of the public and experts on various topics related to this revision. It received 608 responses, 55% of which were from citizens' representatives, who stated that the key provisions of the directive had been "very to somewhat effective and [that] the cost-benefits were proportionate and justified" (EC, 2021).

The second consultation in 2021 was more influenced by the expectations of professionals. There were 285 responses from 22 member states and six other countries (UK, Norway, Switzerland, Serbia, USA and Israel), including 266 responses to the more technical and expert sections. Nineteen percent of respondents represented citizens and only 30 respondents (10.5%) indicated that they had little or no knowledge of the topics of the consultation. Fifteen respondents were scientists, including six who were part of the Co-UDlabs consortium.

3.1. Responses of the 'general public'

In the specific responses of the second consultation, the respondents considered it as "very important" (maximum score of 5) or "important" (score of 4) by more than 70% (n=185) that nature-based solutions (NBS) should play an increased role in managing urban wastewater. The average score of 4.2 reflects the importance attached to these measures. The participants that saw "little (2) to no importance (1) in the future management of waste water" (EC, 2021) were in a minority (5% or n=11).

Most public authorities did not agree with the proposed measures to minimise pollution from stormwater overflows and urban runoff and suggested "Other" as most frequently selected option (score of 4.7). Businesses and citizens preferred with a score of 4.3 "measures relating to obligations for agglomerations to adopt a strategic planning approach of the management and prevention of storm water overflows and urban run-off" (EC, 2021). Other high-rated aspects where "providing guidance strategies to manage pollution" (citizens' score 4.1), "implementation of NBS" (businesses' and citizens' score 4.0) and "risk-based approaches in line with the objectives of the Water Framework Directive" (businesses' score 4.0). As least appropriate measure, public authorities (score 2.9) and businesses (score 3.2) chose "mandatory reporting of overflows".

Overall, the proposed measures on sampling frequency and monitoring were not particularly well rated, with the majority scoring less than 4/5 on average. Providing guidelines for normal operating conditions was generally considered the most feasible measure (average of 4.0). It should be noted that the lowest rated option was to replace chemical oxygen demand (COD) measurements with total organic carbon across all stakeholder groups (average of 2.6).

The first question on innovation was specifically about integrating EU spatial data services (e.g., CORINE LandCover, satellite images for water features and other remote sensing tools) to improve monitoring and reporting. A large proportion of respondents did not know or had no opinion on the issue (n=74, 28%). The second question asked the participants whether steps should be taken to adapt to technological advances and progress. The statement received over 60% support.

Regarding costs and benefits, the polluter pays principle was the topic receiving the highest average score (4,5) for to be addressed in the revised legislation (68% selected "very important" (5)). 80% gave a score of 4 or 5 to "the promotion of monitoring and tracking of industrial release to urban waste water" (no average score provided). Although 50% of respondents are willing to pay more for additional wastewater treatment, 91% claimed that manufacturers and producers should contribute to the reduction of micropollutants. However, for urban run-off, 69% selected local authorities as responsible group.

The respondents to the survey had three votes for different cost-effective measures, 254 respondents made 693 votes (2.7 votes in average). "Improved stormwater overflow and urban runoff management" received the highest number of votes (n=166 or 24%).

3.2. Responses by Co-UDlabs scientists

The responses of the six Co-UDlabs partners from Spain, France, Switzerland, UK and Germany to the consultation for the revision of the European directive UWWTD and their supplementary comments were recorded separately within the project.

In line with the objectives of Co-UDlabs, the six Co-UDlabs partners believe that the most important topics of the regulatory review are (i) better managing stormwater overflows through an integrated approach and (ii) managing urban runoff, through an integrated approach. Five out of six contributors also consider the following propositions to be important:

- better application of the polluter pays principle, where possible;
- improve the energy performance of the UWWTP; and
- accelerate the adoption of innovation in the urban wastewater sector.

The topics that are of least importance to the Co-UDlabs partners are the reuse of sludge, the use of wastewater monitoring as an early warning system to prevent the spread of potential viruses and pathogens, including Covid19, and the obligation for UWWTPs to ensure energy production.

All six partners gave the highest importance to using NBS in urban wastewater management whenever possible.

The majority of respondents found the proposed definition of the problems in urban wastewater management incomplete and insisted on the need for a more global approach, including the effects of global change. They made complementary propositions and regards in the comment section. With regard to stormwater treatment, these related to:

- Improved and cost-effective monitoring;
- Joint and transnational research activities;
- The inclusion and analysis of spatial data;
- Paying more attention to combined sewer overflows;
- More flexibility in adapting treatment processes to current technological developments; and
- Using a more integrative vocabulary with wet weather flow, rather than stormwater.

All weighted answers to the UWWTD survey and the additional comments can be found in Table A.2 (Annex 2).

4. Evaluation and synthesis of the different needs and visions

4.1. National roadmaps

The approaches in the "national roadmaps" towards transitioning to a more sustainable stormwater management adapted to the impacts of climate change are quite diverse, reflecting the different political and societal structures of the countries represented in the project, as well as the different climate conditions. In order to compare the needs expressed in the legal and policy documents, we developed a table based on the themes of interest within the project (Figure 2) and the most common aspects identified in the national guidelines and legislative documents. This table contains the need-based criteria:

(i) Scientific Knowledge,

(ii) Techniques and Technologies,

(iii) Non-technical Solutions, and

(iv) Knowledge Transfer/Training of Practitioners,

following different categories dealing with

(i) Technical Objects,

(ii) Processes, Impacts and Risks,

(iii) Urban Services and Urban Planning, and

(iv) Water Cycle,

Different categories and criteria are represented in the grid of Table 1. For each country, the needs identified in the documents evaluated for the subchapters 2.1 to 2.7 were sorted into the different fields. After comparing the entries, those with a similar content were merged, which resulted in the Table A.1 in Annex 1. Table 1 gives a quantitative overview, which is presented as follows:

- The number of countries which expressed a need regarding the specific topic is noted in the top circle.
- The number of entries from all assessed documents is noted in the left circle, since more than one need was expressed by some countries.
- The number of ideas in the right circle reflects the total number of needs expressed in all roadmaps since sometimes the same needs were expressed in the documents of different countries.
- The darker the shade of blue, the more countries were concerned; the darker the shade of yellow, the more entries were made; red indicates the amount of different ideas existing.

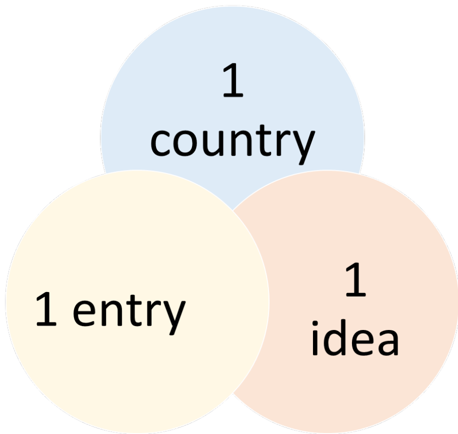


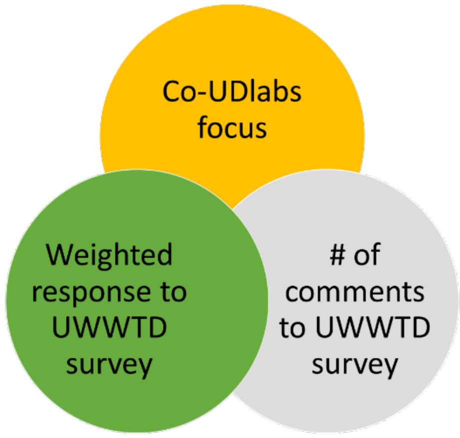
Table 1. Needs expressed in the legislation and policy documents of Denmark, France, Germany, Spain, Switzerland, The Netherlands and United Kingdom, quantitative overview

Categories	Criteria	Scientific knowledge	Techniques and technologies	Non-technical solutions	Knowledge transfer – training of practitioners
Technical objects	**Performance**	6 countries, 10 entries, 6 ideas	2 countries, 3 entries, 2 ideas	4 countries, 7 entries, 6 ideas	4 countries, 11 entries, 10 ideas
	Assets deterioration	4 countries, 8 entries, 5 ideas	4 countries, 4 entries, 3 ideas	3 countries, 5 entries, 5 ideas	3 countries, 3 entries, 1 idea
	Digital water solution	4 countries, 8 entries, 8 ideas	5 countries, 10 entries, 7 ideas	3 countries, 3 entries, 3 ideas	4 countries, 8 entries, 6 ideas
Processes, impacts, risks	**Urban flooding**	5 countries, 9 entries, 6 ideas	4 countries, 5 entries, 5 ideas	5 countries, 6 entries, 6 ideas	4 countries, 8 entries, 7 ideas
	Runoff pollution	7 countries, 17 entries, 11 ideas	5 countries, 11 entries, 8 ideas	4 countries, 6 entries, 4 ideas	3 countries, 3 entries, 3 ideas
Urban services, urban planning	**Waterwise Cities**	4 countries, 5 entries, 5 ideas	4 countries, 6 entries, 6 ideas	4 countries, 6 entries, 5 ideas	4 countries, 9 entries, 7 ideas
Water cycle	**Water resources**	3 countries, 4 entries, 4 ideas	3 countries, 3 entries, 3 ideas	5 countries, 7 entries, 6 ideas	1 country, 1 entry, 1 idea
	Adaptation to climate change	4 countries, 6 entries, 4 ideas	6 countries, 6 entries, 5 ideas	3 countries, 5 entries, 5 ideas	2 countries, 2 entries, 2 ideas

As a general result, there is a large heterogeneity of the expressed needs. The only field with entries from more than one country with 100% accordance is dedicated to 'Technical objects - Assets deterioration / Knowledge transfer', for which the need 'to train professionals to improve self-monitoring, knowledge of the state of the works and critical thinking' was expressed in the analysed documents of France, Switzerland and the Netherlands. With 37.5% accordance for 'Scientific knowledge', 25% for 'Techniques and technologies' and none for 'Non-technical solutions', this was also the sub-category with the highest overall accordance. However, the general interest was limited with 3 to 4 countries per criteria (average of 3.5). The highest interest was dedicated to the sub-category of 'Runoff pollution' within 'Processes, impacts, risks' with 3 to 7 countries expressing needs for the different criteria (average of 5) and an accordance of 35% for 'Scientific knowledge', 27% for 'Techniques and technologies' and 33% for 'Non-technical solutions' (no accordance for Knowledge transfer – training of practitioners). This topic also received overall the highest number of entries, in average 9.25 entries resulting in an average of 6.5 needs expressed ('ideas') per criteria. The second highest global interest was expressed for 'Technical objects – Performance' with in average of 4 countries, 7.9 entries and 6 ideas, respectively. The lowest result was received for 'Water cycle – Water resources' with 1 to 5 countries per criteria (average 3.25), and an average number of 4.25 entries and 3.5 ideas.

4.2. Co-UDlabs participants

The evaluation of the two sources available for the expressed needs and visions of the Co-UDlabs participants followed the same logic as for the national roadmaps. These sources were the Co-UDlabs proposal and the replies to the survey on the UWWTD revision, as described in section 3.2. They were evaluated and made visually comparable as follows:



- A topic that is treated in the Co-UDlabs proposal is shown by the top circle.
- Six partners responded to the survey that was part of the impact assessment on the revision of the Urban Wastewater Treatment Directive (UWWTD). All answers related to stormwater were evaluated. Since answers could be given on a scale from 1 (not at all agreed) to 5 (completely agreed), we calculated an approval factor using weighting factors of 0/0.25/0.5/0.75 or 1 for a response of 1/2/3/4 or 5. The highest value for one response is 6 (all six partners fully agreed on the topic). The values are noted on the left circle.
- To each topic, the survey on the UWWTD allowed comments. The number of comments provided is noted in the right circle.
- The darker the shade of green, the higher the approval to the question on the UWWTD; for grey, it shows the number of comments that were given.

This procedure finally resulted in Table 2.

Table 2: Needs expressed by the Co-UDlabs project partners, quantitative overview

Categories	Criteria	Scientific knowledge	Techniques and technologies	Non-technical solutions	Knowledge transfer – training of practitioners
Technical objects	**Performance**	Co-UDlabs; 1 comment	Co-UDlabs; UWWTD 4.75; 1 comment		UWWTD 6
	Assets deterioration	Co-UDlabs			
	Digital water solution	Co-UDlabs; 2 comments	Co-UDlabs; 3 comments	Co-UDlabs; 3 comments	Co-UDlabs; 2 comments
Processes, impacts, risks	**Urban flooding**				
	Runoff pollution	Co-UDlabs; 2 comments	1 comment	UWWTD 5.5; 5 comments	4 comments
Urban services, urban planning	**Waterwise Cities**		UWWTD 5.75	Co-UDlabs; UWWTD 5.75; 6 comments	Co-UDlabs; UWWTD 5
Water cycle	**Water resources**			UWWTD 6; 1 comment	

Categories	Criteria	Scientific knowledge	Techniques and technologies	Non-technical solutions	Knowledge transfer – training of practitioners
	Adaptation to climate change	1 comment	1 comment	1 comment	

It is hardly surprising that the entries resulting from the Co-UDlabs project description are strongly present in the column for 'Scientific knowledge'. While the responses and comments to the consultation of the UWWTD were strongly guided by the questions asked, it is interesting to see that the most overall comments were made on the topic of 'Digital water solutions' almost equally distributed to all criteria. This shows that the project participants see a real need to implement new technologies and improve their use on all levels, which is also one of the strong foci of the Co-UDlabs project.

The single aspect receiving the highest interest were 'Urban services, urban planning – Waterwise Cities' and 'Non-technical solutions' (6 comments). These comments target mostly regulatory issues with a general impact on the water management in a city, e.g.:

- Enforcing holistic planning by including other disciplines such as urban planners;
- Other aspects than technical ones into guidelines, such as socio-economic aspects;
- Allowing to adapt to technological development more flexibly than in current legislative frameworks;
- Incentives to improve monitoring and data quality.

'Processes, impacts, risks – Runoff pollution' received 5 comments for 'Non-technical solutions', which also targeted mostly changes in organisational and legislative aspects, such as reversing the preferential treatment of centralised solutions towards decentralised ones and joining the organisational responsibility for stormwater and wastewater.

4.3. Positioning of RI users

A central role in the transitioning to more sustainable urban drainage systems is dedicated to the focus group targeted by the Co-UDlabs project due to their potential interest in using the available research infrastructure (RI) platforms. This group consists of small and medium enterprises (SME), industry, engineering consultancies, but also research groups without own platforms or actors in civil service with responsibility in the field of urban drainage. To get their idea of the future development in urban drainage, we developed a survey based on the needs and vision assessment from the national roadmaps and the Co-UDlabs project. To better visualise the key aspects, we reduced the sub-categories of 'Technical objects', 'Processes, impacts, risks', 'Urban services, urban planning' and 'Water cycle' and combined Table 1 and Table 2. The resulting Table 3 reflects the outstanding interest for 'Technical objects' at all levels and considered sources, although 'Processes, impacts, risks' received almost the same attention. However, it is also interesting to note that for all categories, 'Non-technical solutions' were considered important in both evaluation groups. The complete survey can be found in Annex 3.

Table 3: Focuses of needs combined of country roadmaps and Co-UDlabs partners

Criteria / Categories	Scientific knowledge	Techniques and technologies	Non-technical solutions	Knowledge transfer – training of practitioners
Technical objects (Performance, Assets deterioration, Digital water solutions)	6 countries 26 entries 17 ideas Co-UDlabs 3 comments	5 countries 18 entries 12 ideas Co-UDlabs UWWTD 4.75 1 comment	6 countries 14 entries 13 ideas Co-UDlabs 3 comments	5 countries 22 entries 15 ideas Co-UDlabs UWWTD 6 2 comments
Processes, impacts, risks (Urban flooding, Runoff pollution)	7 countries 26 entries 17 ideas Co-UDlabs 2 comments	6 countries 16 entries 13 ideas 1 comment	5 countries 12 entries 8 ideas UWWTD 5.5 5 comments	5 countries 11 entries 10 ideas 4 comments
Urban services, urban planning (Waterwise Cities)	4 countries 5 entries 5 ideas	4 countries 6 entries 6 ideas UWWTD 5.75	4 countries 6 entries 5 ideas Co-UDlabs UWWTD 5.75 6 comments	4 countries 9 entries 7 ideas Co-UDlabs UWWTD 5
Water cycle (Water resources, Adaptation to climate change)	4 countries 10 entries 8 ideas 1 comment	4 countries 9 entries 8 ideas 1 comment	5 countries 12 entries 11 ideas UWWTD 6 2 comments	2 countries 3 entries 3 ideas

The questionnaire was distributed in the form of an online survey, and the seven Co-UDlabs members disposing research platforms invited contacts from their network to participate. Additionally, the link to the survey was also presented at the 10th International Conference on Sewer Processes and Networks in Graz, Austria, in August 2022. Despite all efforts, the number of respondents remained quite low and limited to participants from four countries. Figure 5 gives an overview on who provided feedback.

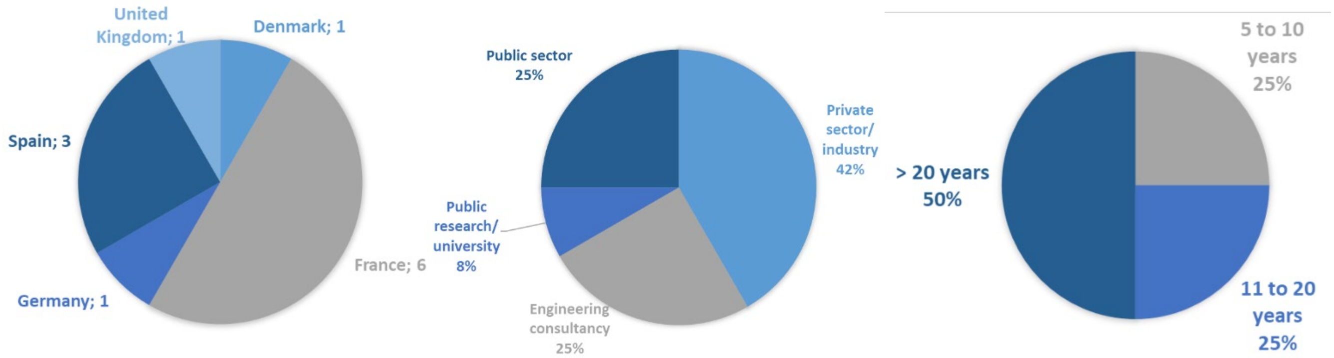


Figure 5: Country of residence, job sector and seniority in the water sector of the (potential) RI users responding to the questionnaire on the needs and visions assessment

In the first part of the survey, the participants were asked whether they agreed with the selected criteria and categories. While overall, most respondent were more or less agreeing with the suggested categories and criteria, some participants (3) mentioned problems in understanding the general purpose of the table or how to interpret it. As more detailed feedback, some suggestions were made on the categories and criteria, e.g., to add the following additional subcategories:

- For "Technical objects":
    - Subcategory "Requirements" in addition to "Performances", which would more clearly include the concepts of "Sizing/dimensioning/suitability/adequacy" dealing with the required or recommended conditions of use of the technical objects to ensure that the design is fit for purpose.
- For "Processes, impacts and risks":
    - Sediment transport
    - Receiving waters impact
    - Sewer processes
- For "Urban services, urban planning":
    - "Multi-purpose solutions" such as impermeable surfaces and vegetation, low-carbon and low-impact solutions (reuse of local materials, etc.)
- For "Water Cycle:
    - Wastewater treatment plants and receiving waters since the interconnection of urban drainage systems with these components is key to understanding occurring problems and to propose adequate solutions.
    - Circularity/valorisation related to resources management (energy consumption, chemical reactives, etc.)

The following additional criteria were suggested:

- Finances;

- Information of a larger public;
- Training of end users;
- Operation of treatment facilities/operation and maintenance.

One respondent criticised that the same weight was given to “digital water solutions” as to “performance” and “assets deterioration” in the category “Technical objects”, as this would give too much importance to this aspect. Another participant criticized that “digital water solution” is too a broad term and should be precised whether it refers to sensors and instruments; real time control and/or operation; data analysis and data curation, or others. Another one remarked that the limits between the categories were not clear as flooding should have been included in “Water cycle” as part of “adaptation to climate change”.

This shows a limit of the chosen approach: the selected classification into categories and criteria allows creating a general overview, but risks at the same time to over simplify complex topics; additionally, some aspects could be assigned to different fields in the table.

In the second part of the survey, the participants were asked to position themselves to the evaluation presented in Table 3. Three participants criticised that the focus from the national roadmaps as well as from the Co-UDlabs project summarized in Table 3 was too strongly put on “Technical objects” and “Processes, impacts, risks”, while one participant mentioned that he or she especially agreed with this emphasis. The critics justified their position by stating that all of the categories are of importance in different phases and to different people with different focus; and while urban services and the water cycle seem less popular, they seem to be the subjects of the future in which scientists and technicians must take an interest.

When being asked which specific needs the participants see for the different criteria, there were two kinds of response: while one group named the field or criteria they considered most important, the other made concrete suggestions. In Annex 4, Table A.3, the weighting of the different fields and criteria is given, and the concrete suggestions in Table A.4.

In the third part of the survey, we asked how useful the respondents considered the offer made in Co-UDlabs: Within the project, 17 different stormwater pilot installations in seven research infrastructures can be tested, which includes training and technical support. The ambition of the network is to participate in the evolution of practices and regulations at European level. To do this, the partners propose:

- coordinated research programmes to improve knowledge;
- hosting partners at the seven research infrastructures, for new partnerships and in particular the development of technologies;
- a training and skills development offer.

Four participants found the offer interesting for themselves or their company/institution, especially the option to use the test facilities, one specifically mentioned to be interested in the Co-UDlabs call for Transnational Access in October 2023 to test their SUDS. Four respondents mention to have an ongoing collaboration with one of the Co-UDlabs partner institutions, which (i) helps them to keep their R&D state-of-the-art, (ii) will have direct impact on inspection procedures, (iii) facilitates and promotes the development of common scientific knowledge, and (iv) allows a partnership approach to product development, combining academic and commercial input. One of these respondents added that it would be interested to develop specific further techniques and technologies in the field of stormwater filtration and that a collaboration with an institution enabling such investigations would be welcomed.

Another four participants underlined the general interest of training and skills development offers, emphasizing the importance of qualification of skilled workers in the connected services, but also a training of community managers and elected officials.

In terms of future partnerships that would be effective in developing the participants' practices, one respondent from a private service provider suggested pilot installations at their sites in collaboration with the municipality, and another participant with an industrial background suggested increased collaborations with between research centers, University technology departments and service providers. The importance of including industry into the development was as well emphasized by another respondent, who suggested initiating a catalogue of innovative products. Another participant mentioned while partnerships with research infrastructures are essential, municipalities should be equipped to evolve their practices and to share it with other municipalities. Additionally, the immanent need for funding for smaller companies when developing new products was mentioned.

As feedback to the request of finalising a key phrase, the following sentences were submitted:

"For me, the priority in transitioning to more sustainable stormwater management is…":

- "strong engagement and participation of the full range of stakeholders."
- "R&D and new technologies."
- "understanding of future events, so that the resilience of cities can be maximised."
- "the knowledge and understanding of these issues by our elected representatives..."
- "in the choice of our models of society and the organisation of our cities, and therefore in the hands of political bodies."
- "changing practices and disseminating knowledge."
- "the protection of citizens during heavy rainfall events."
- "to have tools and frameworks, to work in a more integrated way, from planning, to project and works, and finally to exploitation and maintenance of urban drainage systems."
- "MONITORING. Monitoring is first."
- "to consider stormwater as a resource and not as a waste and promote on-source practices to reuse it with the most possible quality."

The approach chosen for the survey was also presented during a conference in Rennes, France, in June 2022 ("Carrefour des gestions locales de l'eau de Rennes"). Approximately 25 participants, mostly from public water utilities and municipalities, were then asked to write down their anticipated needs and add it to a poster image of Table 3, resulting in 18 entries, which were added to Table A.4. A major focus was on Technical Objects – Performance, for the criteria Scientific knowledge, Techniques and technologies and Non-technical solutions with a total of 7 entries (6 ideas).

5. Common needs and visions

All three sources used for the needs assessment – national roadmaps, input of Co-UDlabs participants and potential RI users -, resulted in various needs that were pointed out. However, looking at the different propositions, some needs could be summarised. Table 4 gives an overview of the different sources per underlined topic in the sections 5.1 to 5.4. A need had to be mentioned at least twice by different initiators to be included.

Table 4: Guiding topics derived from the expressed needs in the three evaluated sources, which require (near) future activity

Categories		Scientific knowledge	Techniques and technologies	Non-technical solutions	Knowledge transfer – training of practitioners
Technical Objects	Performances	Data collection and quality	Sewer infiltration	Integrated stormwater management	Standardisation
Technical Objects	Performances	Maintenance and long-term evolution	Adaption of sewer systems	Multi-stakeholder gouvernance	Network creation
Technical Objects	Performances	Standardise assessment	Soil infiltration		
Technical Objects	Performances	Treatment of highly variable flows			
Technical Objects	Assets deterioration	Sewer processes	Data collection and analysis	Management of assets	Training of professionals
Technical Objects	Assets deterioration	Performance and resilience		Costs and investment	
Technical Objects	Assets deterioration	Big data			
Technical Objects	Digital water solution	Advanced monitoring	Advanced monitoring	Citizen involvement	Training for monitoring devices
Technical Objects	Digital water solution	Data management and modelling	Data management	Organisational issues	
Technical Objects	Digital water solution		Modelling		
Processes, impacts, risks	Urban flooding	Predictive models and risk maps	Predictive models and risk maps	Predictive models and risk maps (support)	Case-studies and demonstration-scale projects
Processes, impacts, risks	Urban flooding				Preventative flood management
Processes, impacts, risks	Runoff pollution	Monitoring of contaminants	Data collection and model development	Financial aspects	Training on metrology
Processes, impacts, risks	Runoff pollution	Impact of pollutants	Runoff management	Sustainable stormwater solutions	
Processes, impacts, risks	Runoff pollution	Pollutant dynamics		Integrated planning	
Processes, impacts, risks	Runoff pollution	Modelling			
Urban services, urban planning	Waterwise Cities	*No common topic could be identified.*	Design approaches and strategies	Governance structure	Tailored training activities
Urban services, urban planning	Waterwise Cities			Local responsibilities	Available research infrastructures
Urban services, urban planning	Waterwise Cities			Boosting innovation	Information for the public
Water cycle	Water resources	Impact of wet weather dischargers on receiving waters	Predictive models	Adaptation of legislation to an integrated water resources management	*No common topic could be identified*
Water cycle	Water resources	Prevention and restoration of surface waters			
Water cycle	Adaptation to climate change	Integrated and holistic models	Make technical choi-ces and regulations climate-proof	*No common topic could be identified.*	*No common topic could be identified.*
Water cycle	Adaptation to climate change	Anticipating the effects of global change on existing sewer systems			

(blue dots) number of needs found in the national "roadmaps" referring to this topic
(orange dots) number of needs named by different Co-UDlabs participants or in the proposal
(yellow dots) number of needs named by (potential) RI users

5.1. Technical Objects

5.1.1. Performances

More **scientific knowledge** with by far the most interest was specifically requested around data collection, data quality and their use in modelling. Three other topics resulted in two entries each from two different sources:

- on the evaluation of maintenance and long-term evolution of urban drainage assets.
- on how to standardise assessment of UDS performances, e.g., by transnational approaches as chosen in the Co-UDlabs project.
- regarding the treatment of highly variable wastewater flows impacted by stormwater.

For all other criteria, a variety of suggestions with only few overlaps were made. To be named here are for **techniques and technologies** the identification of sewer infiltration, adaption of sewer systems and soil infiltration; for **non-technical solutions**, integrated stormwater management and multi-stakeholder governance. Standardisation of guidelines and planning materials as well as network creation were addressed at least twice in **knowledge transfer and training of practitioners**.

5.1.2. Assets deterioration

The entries for developing **scientific knowledge** resulted in three main groups, which were:

- Investigations on sewer processes leading to corrosion.
- Long-term performance and resilience of UDS and NBS.
- The use of big data, especially for modelling.

Data collection and analysis was the most common point for the criterion **techniques and technologies**. More interest was expressed for **non-technical solutions** around the management of assets and questions of costs and investment strategies. For **knowledge transfer**, training of professionals to improve self-monitoring, knowledge of installations and critical thinking was identified as consistent need.

5.1.3. Digital water solutions

For Digital water solutions, three topics were mostly named for both **scientific knowledge** and **techniques and technologies** across all sources, which are

- Advanced monitoring, such as the use of interconnected smart monitoring techniques;
- Improved data management and evaluation, e.g. through data harmonization and sharing; and
- Modelling, e.g. integrated models for parts of the sewer infrastructure as well as holistic models for the sewer, WWTP and surface waters.

Citizen involvement and public access to collected data is the most considered aspect for **non-technical solutions.** Other widely named aspects are around organisational issues, e.g. for data management questions and agreements on data requirements. In **knowledge transfer and training of practitioners**, the major issue is training for new monitoring devices and development of strategies for their use. There are various other needs named, but uniquely once per topic and source.

5.2. Processes, impacts, risks

5.2.1. Urban flooding

This topic is uniquely covered by the national "roadmaps", there were no entries from the other sources. **Scientific knowledge** and **techniques and technologies** are mainly requested for predictive models and risk maps, which is also referred to under **non-technical solutions** (e.g., support of their creation). For **knowledge transfer**, the national "roadmaps" suggest several means, e.g., case studies and demonstration-scale projects, and **training of professionals** in the design and operation of existing networks for preventative flood management, among other suggestions.

5.2.2. Runoff pollution

For the sub-category of runoff pollution, by far the most needs were formulated, which can be found in all three sources used for this assessment.

More **scientific knowledge** is requested for:

- monitoring of contaminants, and pollutant sources, especially with regard to the quality of the obtained data;
- the impact of pollutants on the environment, e.g., on surface waters, groundwater or the soil used for infiltration;
- the dynamics of pollutant accumulation and transport; and
- modelling around runoff events.

Data collection and model development as well as runoff management especially with NBS were the two consistent topics in **techniques and technologies.**

According to this assessment, **non-technical solutions** should mainly focus on:

- financial aspects: Unified taxation for discharge of nutrients from stormwater outlets and CSOs and better application of the polluter pays principle.
- following sustainable stormwater solutions resulting in disconnection for stormwater for infiltration, a privileged treatment with NBS or reuse.
- developing an integrated planning for stormwater.

Training on metrology was the only common point named for **knowledge transfer and training of practitioners**.

5.3. Urban Services, urban planning - Waterwise cities

No need pointed out for **scientific knowledge** was mentioned by more than once; five out of the seven different entries can be found in the national "roadmaps" (Table A.1). Development of design approaches and strategies for urban planning, including the evolution of standards for the building industry was at the most addressed topic in **techniques and technologies**. **Non-technical solutions** was the criterion receiving the most entries, with three identified topics:

- Governance structure on different levels: Necessity of implementing clear structures between the different stakeholders; holistic planning in urban planning by establishing frameworks and open policies
- Local responsibilities: Allow local operators to develop their own action plans, e.g., by also strengthening inter-municipal cooperation.
- Boosting innovation: Accelerate the adoption of innovation, e.g., by explicitly opening the inclusion of new technologies in regulatory frameworks.

The entries for **knowledge transfer and training of practitioners** enabled as well to identify three topics:

- Develop tailored training activities on urban drainage, especially on stormwater management, for different stakeholders
- Create an overview of available research infrastructures and enable access and network creation.
- Provide information for the public.

5.4. Water cycle

5.4.1. Water resources

The entries for developing **scientific knowledge** resulted in two main groups, which were:

- Impact of wet weather discharges on receiving water.
- Prevention and restoration of surface waters.

The development of predictive models was the most common point for the criterion **techniques and technologies,** and Adaptation of legislation to an integrated resources management for **non-technical solutions**.

5.4.2. Adaptation to climate change

Only two criteria resulted in corresponding needs, which were for **scientific knowledge**, developing of integrated and holistic models as well as anticipating the effects of global change on existing sewer systems, and to make technical choices and connected regulations climate-proof for **techniques and technologies**.

5.5. Outlook

Overall, the evaluation shows that the particular needs for Urban Drainage Systems identified by the different stakeholders are quite diverse, and could not be limited to major axes. In fact, there are numerous needs identified, which indicates what a great effort still needs to be made for transitioning to a sustainable urban drainage system.

Only very few of them were mentioned by all three considered sources – country roadmaps, Co-UDlabs participants and (potential) RI users (Table 4). While this is also due to the limited number of responses from the RI users, it also could indicate that more interaction between the different stakeholder groups are necessary, which is one goal of the Co-UDlabs project.

Some of the identified needs are quite in line with the visionary documents of IWA and Water Europe summarized in section 1. It is interesting to see that all questions around (real-time) big data management and advanced monitoring and training in these technologies were mentioned quite often in the different sources, while Water Europe proposed these aspects in their Strategic Innovation and Research Agenda (SIRA) as “shorter to medium impact measures” for the years 2017-2021 as the first stage of a three-stage to shift the European Water System (Water Europe SIRA, 2016). This shows that while awareness of the importance of these topics is developing at the different stakeholders, concrete actions in many cases still need to follow.

The evaluation of the organisation and legislative structure in the countries represented in this project also can be a source of slowing down innovation in the urban drainage sector. Hence, integrated planning of the water sector, which was one of the points mentioned for different criteria and categories, and clarifying responsibilities, should be implemented rather sooner than later.

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Annex 1. Summary of national road maps.

Table A.1: Needs expressed in the different country roadmaps regarding stormwater management issues.

		Scientific knowledge	Techniques and technologies	Non-technical-solutions	Knowledge transfer – training of practitioners
Technical Objects	Performance	Data driven modelling with AI to develop system knowledge	Identify sewer infiltration	Multi-stakeholder governance / accountability	Create demonstrators of the different techniques
			Pollution-based RTC algorithms	Holistic planning process	Transdisciplinary conferences
		Effectiveness of different strategies of maintenance and sediment management		Maintaining assets with more limited investment and net zero constraints	Support for national research and development programs (MUDP, VUDP)
		Data quality of available performance monitoring data		Incentives for integrated management of UDS and WWTPs	Standardized planning to integrate sponge city concepts into city development
		RTC control / Remote sensing		Inform on stormwater management benefits	Use of data and interpretation of model results
		How WWTPs can deal with diluted wastewater		National roadmap	Train design offices in the sizing of stormwater management facilities at source
		Common standards/metrics to assess the performance of UDS			Train state services for the regulatory instruction of stormwater files
					Enhance the results of research on the performance of different stormwater management solutions
					Network building among water utilities
					Climate change adaptation documents
	Asset deterioration	Corrosion of concrete structures from hydrogen sulphide / Improve the knowledge on pipe deterioration	Measuring and data analysis for all infrastructure	Encourage gathering for better management of assets	Train professionals to improve self-monitoring, knowledge of the state of the works and critical thinking
			Modelling and controlling corrosion in pumping systems	Develop interactions with the other public utilities	
		Improve the knowledge on NBS medium- to long-term performance / Deterioration models of NBS	New techniques to map and monitor systems	Development of models for buried assets deterioration - rehabilitation costs	
				New data models accessible to the various departments of the utility	
		Use of big data / Data-driven models to failure of assets			

		Fundamental knowledge on the processes				Assess inter-generational fairness regarding investment strategies			
		Sewer leakage							
	Digital water solution	Free meteorological data from National Meteorological service		IoT sensor network in urban areas / RTC- sewer flow control / Implementation of IoT – Big data – Water digitalization		Administration: Designing a water data strategy		Case study descriptions	
								Predictive maintenance solutions	
		Development of AI – Data driven models				Customer involvement in big data collection		Monitoring data management systems (reliable archive)	
		Dynamic precipitation risk maps		Data/model fusion		Organisational issues, organisational forms (jointly operate UDS and WWTP), competences of utilities		Transdisciplinary conferences	
		IoT sensors in the natural and urban water cycle		Data sharing and crowdsourcing				How to use Digital twins in a proper manner	
		Real time rainfall-runoff predictions		Algorithm for automated data quality assessment				Train the professionals in tools for using self-monitoring data for better management of the assets of the facilities	
		Assess the holistic value of monitoring data (for operation, planning, compliance assessment)		Predictive maintenance solutions					
				Monitoring data management systems (reliable archive)					
		Urban drainage ontology to facilitate machine-to-machine communication for UDS data, model predictions, etc.)		Cybersecurity issues					
		Development of digital twins							
Processes, impacts, risks	**Urban flooding**	Development of urban risk maps /models related to flooding/climate change		Nationwide standardized rainfall information for flood risk assessment		National service for weather radar forecasting dedicated to urban drainage applications		Train professionals in the design and operation of existing networks for preventive flood management	
		Detailed rainfall information & future rainfall prediction models / Extreme weather predictions especially associated with climate change		Implementation of NBS		Develop solutions to reduce imperviousness, to disconnect impervious surface		Demonstration projects of flood protection	
				Field observations+ use of historical data					
				Flooding risk assessment maps		Development of Integral Master Planning		Case study descriptions of emerging concepts	
		Assimilation between weather radar and numerical weather predictions (NWP)		Remote sensing (e.g. satellites, drones...) for pluvial flood monitoring		Support with creating hazard and risk maps for local heavy rainfall events		Transdisciplinary conferences	
								Advocacy for use of SuDS	
		Runoff from pervious areas				Organisational issues, organisational forms (jointly operate UDS and WWTP)		Monitoring data management systems (reliable archive)	
		Urban pluvial flood data							
		Weather radar now-casting				Competences of utilities		Predictive maintenance solutions	

Processes, impacts, risks	Runoff pollution	Knowledge/monitoring of contaminants (macro & micro) and pollution sources	Metrology: to improve discharge monitoring and data management	Unified taxation for discharge of nutrients from stormwater outlets and CSO	Train operators on metrology and self-monitoring of wastewater systems
		Emerging contaminants	(Pollution-based) RTC control	Development of Integral Master Planning	Stormwater treatment demonstration projects
		Impact of emissions on the society (bathing water) / Microbial pollution regulations	New methods for measuring CSO - both volumes and pollution	Conception and implementation of a long-term communication strategy aimed at different target groups, incl. "importance of wastewater disposal", "adaptation to climate change", "rainwater infiltration"	How to interpret and use data on runoff quality (and quantity)
		Impact of emissions on the environment (particulates, toxicity vs. chronic pollution, pesticides, heat, GHG, ...)	Disinfection of overflow discharges Implementation of NBS		
		Predictive / detailed models	Bathing water impact evaluation	Guideline for sponge city UDS	
		Hybrid software sensors for online measurement of derived pollutants	Accurate high-resolution rainfall observations		
		In case of infiltration, the pollutant load of rainwater is to be taken into account to protect groundwater from contamination	Real-time models for rainfall-runoff (maybe data-driven)		
		CSO and stormwater monitoring			
		Dilution of emissions in surface waters			
		Suitability of runoff for cooling cities			
		Models for particulate transport from the atmosphere to the receiving water			
		Error models to describe uncertainties associated with rainfall			

Urban services, urban planning	Waterwise Cities	Long-term performance of SUDS	🇩🇰	Monitoring of SUDS performance on a large spatial and temporal scale	🇩🇰	Better integrate stormwater management with urban planning	🇫🇷 🇨🇭	Training programme for local decision makers, professionals and planners on planning aspects, ecological and technical points / source control solutions	🇫🇷 🇩🇪
		Use of AI to develop system knowledge from data	🇬🇧	Water balance tools for urban planners	🇨🇭	Indicators to evaluate co-benefits of NBS	🇨🇭		
		Decentralised systems	🇨🇭	Mapping of unintended runoff into urban drainage systems/ groundwater infiltration	🇩🇰	Establish stormwater management zones in urban planning documents before 2026	🇫🇷	Translation of scientific knowledge into guidelines for design operation and control	🇩🇪 🇳🇱
		How to keep streams of water with various qualities separated	🇳🇱						
		Microclimate modelling - > role of stormwater to decrease air temp	🇨🇭	Improve the ability to integrate water management planning into overall spatial planning	🇩🇪	Further development of inter-municipal cooperation in wastewater disposal and strengthen administration	🇩🇪	Train the eco-district experts in stormwater management	🇫🇷
								Involve citizens in the maintenance of urban water systems (e.g. NBS)	🇨🇭
				Develop the model of the "waterwise city" (sponge city) and put it into practice.	🇩🇪	Clear governance structures (regulators, operators, owners and citizens)	🇪🇸	Develop and enrich mapping observatories of stormwater source control solutions	🇫🇷
				Risk based design and management, strategies to be developed	🇳🇱			Network of places of experience and learning: Creation of a nationwide network of educational institutions, places of experience and learning with a focus on water for the promotion of young people	🇩🇪
								Explore social media platforms to inform the public	🇨🇭
Water Cycle	Water resources	Monitor and model river courses and maritime areas - CSO impacts	🇪🇸	The priority of near-natural rainwater management measures is to be strengthened in communal urban land use planning.	🇩🇪	Support the application of the legislation related to balanced and sustainable water resource management	🇫🇷 🇨🇭	Give insight in the long-term evolution of the quality of surface waters and ground water bodies to allow for strategic planned use of resources: reuse of water	🇳🇱
		NBS and groundwater impacts	🇨🇭	High-resolution synthetic rainfall time series with existing and future climate to support planners	🇨🇭	Assign clear responsibilities between stakeholders	🇫🇷		
						Impact assessment according to WFD (self-purification)	🇪🇸		
		Restoration of urban streams and rivers.	🇨🇭	Large scale monitoring + application of predictive models	🇳🇱	Support in establishing structures and capacities for joint data management and knowledge transfer measures	🇩🇪		
		How to prevent contamination of the water system given the delta area we live in	🇳🇱			Cooperation in the international implementation of sustainable water resource management	🇩🇪		

						Alternative permitting to reflect assimilating capability of receiving water body			
	Adaptation to climate change	Use climate predictions in the models		Support NbS		Conception and implementation of a long-term communication strategy for different target groups, incl. "importance of wastewater disposal", "adaptation to climate change", "rainwater infiltration"		Raise awareness of global warming and NBS among elected officials (feedback)	
		Dynamic runoff discharge permits for minimal environmental impact of climate change		Blue spot analysis based on DEM (digital elevation method)		Non-structural measures (SUDS) (e.g. cleaning practices)		Translate insight in expected changes in precipitation and temperature into guidelines regarding (re)design of systems and their operation.	
		Integrated models to describe water-energy-nexus		Making (technical) water management regulations climate-proof		Guidelines on how to best use water to cool cities			
		Integrated models to describe urban microclimate and biodiversity of NBS aspects		high-resolution synthetic rainfall time series with existing and future climate to support planners		Standardized approaches for UDS adaptation, so practitioners can communicate in the same language and learn from each other			
				Relevant for all urban drainage infrastructure (esp. rainfall and temperature)		Integrate biodiversity in urban planning			
Other topics		To launch coordinated calls for projects				Citizens perspective - engagement		To host a national network of operators (exchanges of experiences)	
		Financial instruments						Technology transfer from other sectors	
		Planning for trees adapted to climate change							
		Turn wastewater into an urban resource (e.g. water plants and trees)							

Annex 2. Summary of Co-UDlabs needs expressions.

Table A.2: Needs expressed by the Co-UDlabs project partners

		Scientific knowledge	Techniques and technologies	Non-technical-solutions	Knowledge transfer – training of practitioners
Technical Objects	Performance	Monitoring (especially in CSOs and sewers) should really be improved (quality assurance, data validation)	Reducing nutrient discharge into water bodies to avoid potential eutrophication (4.75)		Provide information on how much wastewater is discharged untreated or is treated outside of WWTPs (6)
		Trans-national access to major research installations	Account for impacts of proposed policy changes on upstream sewer collection systems, on their behaviour and performance, and their required evolution / adaptation. The new approach cannot be only an 'end-of-pipe' approach		
			Enable access to fast full-scale testing		
	Asset deterioration	Joint research activities to improve understanding of asset deterioration, secure long-term resilience and sustainability of UDS with more robust, autonomous and interconnected smart monitoring techniques and digital water data analysis tools			
	Digital water solution	Joint research activities to improve understanding of asset deterioration, secure long-term resilience and sustainability of UDS with more robust, autonomous and interconnected smart monitoring techniques and digital water data analysis tools -> Big Data approach	In terms of metrology and diagnosis: it is important to open up to non-traditional methods to enable informed local diagnosis: low-cost sensors, biomonitoring, etc.	It is essential if data is to be curated from EU spatial services in a way that will make it useful to the general public and other organisations not linked to water utilities and existing regulators.	Regarding metrology, new methods (online sensors, etc.) shall be promoted and accepted (with proper evidence of their quality), as traditional sampling and lab analyses are/will be insufficient but seem to be maintained unchanged as strict reference to standards blocks evolution.

Technical Objects	Digital water solution	Develop self-monitoring of sanitation systems, combining measurement and modelling and data processing technologies, in order to have a better knowledge of the functioning of the system, to make it a management and operating tool and to provide indicators for improving the functioning of the systems (beyond mere regulatory compliance)	With the currently available spatial analysis methods and data, we should go for spatially distributed analyses and reporting. This would provide a much more detailed view of the local challenges/ problems and then enable finding possibly more suitable solutions that can be implemented.	Developing of new reporting methods, such as national datasets may be carried out into at least two basins: - Applying FAIR principles (Findable-Accessible-Interoperable-Reusable) https://www.openaire.eu/how-tomake-your-data-fair - Clearly define what the data will be used for before demanding to monitor dozens of parameters. The main reasons are: i) Monitoring is extremely costly ii) Data quality check (pre-post processing) is time-consuming and costly. Without data quality check data can probably be useless. iii) Data requirements are crucial. For instance, we can monitor daily stormwater overflows but this useless for modelling. - Monitoring results have to be available for citizens.	In most cases, only traditional methods are applied (i.e. sampling and then lab analyses). On-line sensors, on-line data, new monitoring techniques should be encouraged. Even discharge measurements (esp. in sewers and on CSOs) are frequently of poor quality. The water sector is, to some extent, very conservative with metrology and monitoring, and significant progress are possible with sensors and digital technologies. The problem is partly due to the fact that most frequently only measurements and analyses made according to existing standards are officially recognized. A more incentive and innovative approach should be developed. There is a lot experience and knowledge in the scientific and research literature since more than 20 years that could be used.
		meaningful monitoring requires good data quality (=> DWA M151)	Harmonizing of data procedures and data sets gathered in the research infrastructures		
			The use of spatial data from EU spatial services must not be ignored, as there are constantly new innovative solutions that protect the environment from the harmful effects of wastewater.		
				I would be very worried about the costs of requiring many more pollutants to be monitored at this moment in time. I would rather encourage that this extended monitoring of pollutants is first done systematically & in a standardised way for several case studies (a selected range of UWWTP sizes, climates and population types) throughout Europe, before deciding whether to request widespread costly monitoring or not. As this seems financially very unfeasible for most EU member states, and if it is then not carefully implemented, the data would be bad/useless/not looked, as you would then also need far more finances to allow for analysing and monitoring this data.	Boosting public access to data
				efficient, harmonised and curated means of access to the data collected within the project	

Processes, impacts, risks	Urban flooding				
	Runoff pollution	Trans-national access to major research installations	Promoting the adoption of decentralised NBS where possible	Managing stormwater overflows, through an integrated approach (6)	Qualification and skills in monitoring and metrology of staff should be developed
		Evidence-based compliance assessment for wet weather discharges based on monitoring data requires some way of how to deal with the very dynamic rainfall load and the incomplete observations of pollutant-discharges from a network.		To establish strategies to organisational bottlenecks, e.g. as in Finland: make the WWTP responsible for treatment of ALL wastewater, while permitting “exceptions” (e.g. during wet weather).	Organizational bottlenecks consist in lacking skills of municipalities in managing their urban drainage infrastructure.
				Set the impact of urban areas into perspective with other pollutant sources	
		The evidence base regarding the impact of wet weather discharges from urban areas is not really rock solid.		In wet-weather periods the directive should tackle the performance of the whole UDS, as stormwater overflows may affect to receiving water quality. Looking into the WWTP, in some rain events, biological treatment is bypassed. Thus, the UWWTD should deal with scenarios in which "partially treated" effluents can be "mixed" with fully treated effluents and consider "intermittent discharges" to water courses. The "compliance" with effluent discharge objectives is thus more complex than the current definition. This is especially critical in large urban drainage systems involving combined sewer networks with large "diluted" wastewater conducted to the WWTP.	As WWTPs have different operating regimes under wet and dry weather conditions, more coherent control, monitoring and management strategies have to be developed considering these two scenarios in the new UWWTD.
					The quality of monitoring is an increasingly serious topic, especially regarding CSOs and sewer systems upstream WWTPs
				Disconnection for NBS: if not required, establish that stormwater management at origin is the preferred solution and that collection in centralised systems is an alternative if this is not possible (not the other way around)	

				Expand stormwater management solutions: 1) infiltration, 2) NBS, 3) reuse	
				Better application of the polluter pays principle, where possible (5)	
Urban services, urban planning	**Waterwise Cities**		NBS should play an increased role in managing urban waste water where possible (5.75)	Accelerate the adoption of innovation in the urban wastewater sector (5.75)	Providing relevant information to the public (5)
				Boosting innovation	Dissemination of project results
				Especially regarding CSOs and sewer systems upstream UWWTPs. Data should be of sufficient quality to have a true evidence base for policy and management. Incentives for good quality data especially regarding CSOs and sewer systems upstream UWWTPs. Data should be of sufficient quality to have a true evidence base for policy and management. Incentives for good quality data	Role of research infrastructure in a more rapid transition to smart and sustainable urban drainage system management will be addressed
					Developing tailored training activities for urban drainage, professionals and junior researchers
					Capacity building of project staff
				It is essential to address the issue in a comprehensive and integrated way	
				Strengthening or imposing regulations on the link with urban planning: responsibility at the origin	
				Regulatory cycles are always long and so often miss opportunities from technological advancement. The new UWWTD should explicitly involve provisions for adaptation, in fact they should ensure it happens.	
				Beyond the regulatory indicators imposed, it is important to trust local operators to make a relevant diagnosis and propose action plans according to priorities (particularly environmental issues).	
				The provisions of the revised UWWTD probably have to be included in the framework of "Best Available Techniques" which also considers socio-economic aspects, and local adaptation (especially for smaller agglomerations).	
				Establishing a framework for project sustainability	
				Promoting smart governance in UDS based on open policies	

Water Cycle	Water resources			managing urban runoff, through an integrated approach (6)	
				Adopting a really integrated approach of wastewater with stormwater / runoff accounting for their global and joint impacts on water bodies (link with the WFD), and not decoupling them in separate regulations	
	Adaptation to climate change	Anticipating the effect of global change (decrease water consumption and related effects on existing sewer systems, i.e. warmer temperatures, higher concentrations, decrease of discharges in sewer systems and potential consequences like longer residence times, increase of H2S and other gas emissions, etc.).	Anticipating the consequences of climate change in technical choices	Anticipating the consequences of climate change in strategic choices	
Other topics				meaningful reporting requires a “good” organizational structure	Boosting smart governance practices, training and empowering of project users and beneficiaries
				More inclusive, open and efficient research and innovation environment	
				Organisation of multi-sectorial projects to better engage the participation of industry and SME users	
Legend		Responses of Co-UDlabs participants to survey on the revision of the UWWTD	Comments on UWWTD survey	Ideas in proposal of Co-UDlabs	

Annex 3. Questionnaire for (potential) users of the research infrastructures.

Introduction

Co-UDlabs is a transnational research project that integrates research and innovation activities in the field of Urban Drainage Systems to address pressing challenges in public health, flood risks and environment.

Partners from seven countries are participating in the project: Denmark, France, Germany, Spain, Switzerland, The Netherlands and United Kingdom. We examined what needs are being articulated for more sustainable urban stormwater management in regulations and policy documents from these seven countries, as well as the Co-UDlabs proposal, using the same analytical framework.

To compare the stated needs, we created a table, with four categories:

(i) Technical Objects,
(ii) Processes, Impacts and Risks,
(iii) Urban Services and Urban Planning, and
(iv) Water Cycle,

which were assessed according to the following criteria:

(v) Scientific Knowledge,
(vi) Techniques and Technologies,
(vii) Non-technical Solutions, and
(viii) Knowledge Transfer/Training of Practitioners.

Table 1 shows the resulting analysis grid.

Part 1 – Needs analysis grid

If you look at this table,

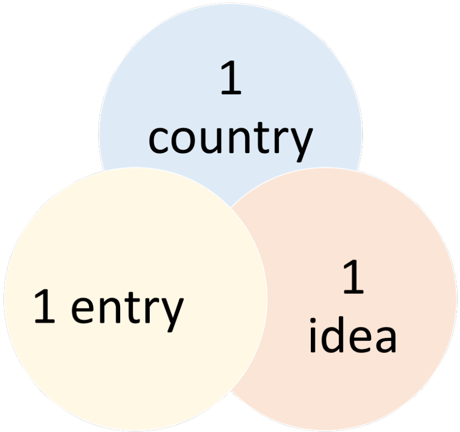
1) What do you think about the different identified categories and criteria?
2) Do they make sense to you?
3) If you don't find the identified categories and criteria useful, what would be better ones for you?

Table 1: Table for needs assessment

Categories	Criteria	Scientific knowledge	Techniques and technologies	Non-technical solutions	Knowledge transfer – training of practitioners
Technical objects	Performance				
	Assets deterioration				
	Digital water solution				
Processes, impacts, risks	Urban flooding				
	Runoff pollution				
Urban services, urban planning	Waterwise Cities				
Water cycle	Water resources				
	Adaptation to climate change				
	Other topics				

Part 2 - Needs expressed by countries and Co-UDlabs partners

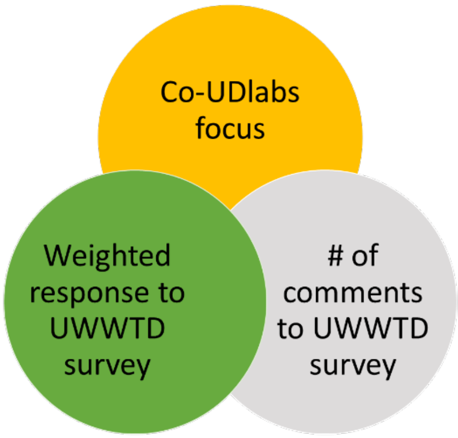
In the next three tables, we will present the results on the needs assessment in the project so far. **Table 2** shows in which fields we found needs expressed in the legislation and policy documents of the countries represented in the project.



- The number of countries which expressed a need regarding the specific topic is noted in the top circle.
- An "entry" is a need mentioned in the legislation and policy documents that was assigned to one of the fields, e.g. "Implementing monitoring equipment" in line Processes, impacts, risks – Runoff pollution" and column "Techniques and technologies".
- The number of entries from all assessed documents is noted in the left circle since more than one need was expressed by some countries.
- Then we looked at each need expressed and compared them. The number of ideas in the right circle reflects the total number of needs expressed in all documents since sometimes the same needs were expressed in documents of different countries (e.g. two countries mentioning the above described "Implementing monitoring equipment" as a need).
- The darker the shade of blue, the more countries were concerned; the darker the shade of yellow, the more entries were made; for red it indicates the number of different ideas existing in the country documents.

We also investigated the needs expressed by the project partners in Co-UDlabs by using two sources (results presented in **Table 3**).

1) The Co-UDlabs proposal itself: A topic that is treated in the Co-UDlabs proposal is shown by the top circle.
2) The survey that was part of the impact assessment on the revision of the Urban Wastewater Treatment Directive (UWWTD) of the European Commission: six project partners responded to the survey. All answers related to stormwater were evaluated.
   - The answers could be given on a scale from 1 (not at all agreed) to 5 (completely agreed) -> we used weighting factors of 0/0.25/0.5/0.75 or 1 for a response of 1/2/3/4 or 5. The highest value for one response is 6 (all six partners fully agreed on the topic). The values are noted on the left circle. The values are noted on the left circle.
   - On each topic, the survey on the UWWTD allowed comments. The number of comments provided is noted in the right circle.
   - The darker the shade of green, the higher the approval to the question on the UWWTD; for grey, it shows the number of comments that were given.



In **Table 4**, you can see both these tables combined for a better overview of the proposals made in national roadmaps and regulations on the one hand, and by the Co-UDlabs project partners on the other.

Looking at the needs expressed by the country policy documents and roadmaps as well as by the Co-UDlabs partners, it becomes evident that some fields received a much higher feedback than others. For Table 2, there is little overlap between the approaches in different national contexts, which results in lots of ideas as not all sources are defining the same needs and are proposing different tools to be implemented. There are also different focuses in Table 2 and Table 3.

If you think about which categories on stormwater management are important to you:

1) Do they match with focuses in Table 2 and/or Table 3?
2) If yes, which needs do you see for these categories?
3) If your priorities of categories do not match the ones in Table 2 and 3, which categories are most important for you?
4) Which needs do you see for these other categories

Table 2: Focuses of needs expressed in the legislation and policy documents of Denmark, France, Germany, Spain, Switzerland, The Netherlands and United Kingdom

Categories \ Criteria	Scientific knowledge	Techniques and technologies	Non-technical solutions	Knowledge transfer – training of practitioners
Technical objects (Performance, Assets deterioration, Digital water solutions)	6 countries; 26 entries; 17 ideas	5 countries; 18 entries; 12 ideas	6 countries; 14 entries; 13 ideas	5 countries; 22 entries; 15 ideas
Processes, impacts, risks (Urban flooding, Runoff pollution)	7 countries; 26 entries; 17 ideas	6 countries; 16 entries; 13 ideas	5 countries; 12 entries; 8 ideas	5 countries; 11 entries; 10 ideas
Urban services, urban planning (Waterwise Cities)	4 countries; 5 entries; 5 ideas	4 countries; 6 entries; 6 ideas	4 countries; 6 entries; 5 ideas	4 countries; 9 entries; 7 ideas
Water cycle (Water resources, Adaptation to climate change)	4 countries; 10 entries; 8 ideas	4 countries; 9 entries; 8 ideas	5 countries; 12 entries; 11 ideas	2 countries; 3 entries; 3 ideas

Table 3: Focuses of needs expressed by the Co-UDlabs project partners

Criteria / Categories	**Scientific knowledge**	**Techniques and technologies**	**Non-technical solutions**	**Knowledge transfer – training of practitioners**
Technical objects (Performance, Assets deterioration, Digital water solutions)	Co-UDlabs 3 comments	Co-UDlabs UWWTD 4.75 1 comment	Co-UDlabs 3 comments	Co-UDlabs UWWTD 6 2 comments
Processes, impacts, risks (Urban flooding, Runoff pollution)	Co-UDlabs 2 comments	1 comment	UWWTD 5.5 5 comments	4 comments
Urban services, urban planning (Waterwise Cities)		UWWTD 5.75	Co-UDlabs UWWTD 5.75 7 comments	Co-UDlabs UWWTD 5
Water cycle (Water resources, Adaptation to climate change)	1 comment	1 comment	UWWTD 6 2 comments	

Table 4: Focuses of needs combined of country documents and Co-UDlabs partners

	Scientific knowledge	**Techniques and technologies**	**Non-technical solutions**	**Knowledge transfer – training of practitioners**
Technical objects (Performance, Assets deterioration, Digital water solutions)	6 countries, 26 entries, 17 ideas; Co-UDlabs, 3 comments	5 countries, 18 entries, 12 ideas; Co-UDlabs, UWWTD 4.75, 1 comment	6 countries, 14 entries, 13 ideas; Co-UDlabs, 3 comments	5 countries, 22 entries, 15 ideas; Co-UDlabs, UWWTD 6, 2 comments
Processes, impacts, risks (Urban flooding, Runoff pollution)	7 countries, 26 entries, 17 ideas; Co-UDlabs, 2 comments	6 countries, 16 entries, 13 ideas; 1 comment	5 countries, 12 entries, 8 ideas; UWWTD 5.5, 5 comments	5 countries, 11 entries, 10 ideas; 4 comments
Urban services, urban planning (Waterwise Cities)	4 countries, 5 entries, 5 ideas	4 countries, 6 entries, 6 ideas; UWWTD 5.75	4 countries, 6 entries, 5 ideas; Co-UDlabs, UWWTD 5.75, 7 comments	4 countries, 9 entries, 7 ideas; Co-UDlabs, UWWTD 5
Water cycle (Water resources, Adaptation to climate change)	4 countries, 10 entries, 8 ideas; 1 comment	4 countries, 9 entries, 8 ideas; 1 comment	5 countries, 12 entries, 11 ideas; UWWTD 6, 2 comments	2 countries, 3 entries, 3 ideas

Part 3 - Offers of Co-UDlabs

In the Co-UDlabs project, 17 different stormwater pilot installations in seven research infrastructures can be tested, which includes training and technical support. The ambition of the network is to participate in the evolution of practices and regulations at European level. To do this, the partners propose

- coordinated research programmes to improve knowledge;
- hosting partners at the seven research infrastructures, for new partnerships and in particular the development of technologies;
- a training and skills development offer.

If you think about your needs in this field,

Do these propositions meet your needs? If so, which one(s) and can you be more specific on your needs?
How does your current partnership with one of the project partners allow you to develop your practices?
Which partnership would you like to develop or would you consider effective in developing your practices?
What other need(s) could you express?

Part 4 - A key phrase

Considering the stormwater management today, could you please complete the following statement:

"For me, the priority in transitioning to more sustainable stormwater management is…"

Statistical questions

We would be happy if you share some information with us.

Please enter your name and affiliation. In no case will this information be published together with your answers without your explicit consent. However, it makes it easier for us to contact you for any queries.

Which country are you currently living in?

□ Denmark

□ France

□ Germany

□ Spain

□ Switzerland

□ The Netherlands

□ United Kingdom

□ Other

Please indicate the sector of your activity.

□ Industry

□ Engineering consultancy

□ Public research/university

□ Public sector

□ NGO

□ Other

How long have you been working in this sector?

□ < 5 years

□ 5 to 10 years

□ 11 to 20 years

□ > 20 years

GDRP - General Data Protection Regulation (UE 2016/679)

Any personal data transmitted through this form will be managed exclusively by Co-UDlabs and in compliance with Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data (GDPR, General Data Protection Regulation).

If you wish to exercise any rights or obtain any information about your personal data as collected through this form, please get in touch with contact@co-udlabs.eu.

Please read Co-UDlabs' terms for the collection and management of personal data before submitting: https://is.gd/CoUDlabs_GDPR.

□ I confirm that I have read and understood the terms linked above AND I consent to the collection and storage of my personal data for the purpose of Co-UDlabs.

Thank you very much for participating! If you are interested in receiving regular information on the Co-UDlabs project, you can add your email address below.

Annex 4. Responses by (potential) users of the research infrastructures.

Table A.3: Combinations of categories and criteria named as most important by the (potential) RI users.

Criteria / Categories	Scientific knowledge	Techniques and technologies	Non-technical solutions	Knowledge transfer – training of practitioners	
Considered as most important criterion				 	**Considered as most important category**
Technical objects (Performance, Assets deterioration, Digital water solutions)					
Processes, impacts, risks (Urban flooding, Runoff pollution)					
Urban services, urban planning (Waterwise Cities)					
Water cycle (Water resources, Adaptation to climate change)		(adaptation to climate change) 	(adaptation to climate change)	(adaptation to climate change) 	

Table A.4: Needs expressed by (potential) users of the research infrastructures

		Scientific knowledge	Techniques and technologies	Non-technical-solutions	Knowledge transfer – training of practitioners
Technical Objects	Performance	in the field of stormwater filtration for its treatment in real time: to promote the removal of pollutants in discharge of sewer overflows both, combined and separated		Economy/Science/Society: value of integrated stormwater management? (2x)	
		Knowledge about the long-term evolution of NBS (performance/ efficiency)	Capacity of the structures for recovery / reuse of stormwater to provide retention of rainfall events with high return frequencies (draining time, optimisation of use etc.)		
		Evapotranspiration in weather forecast ≠ reality in France	Functioning of the pedological part of the soil versus vegetation, evapotranspiration		
			Soil capacity to uptake infiltration		
	Asset deterioration	Technologies related with the sewer processes of sulfide generation and the promotion of concrete asset deterioration in sewers during dry weather periods		Advanced asset management system	
		Bad odours impact in the sewer system		Advanced cleaning management system	
	Digital water solution	to develop instruments for the real-time runoff pollution characterisation based on molecular spectroscopy		To have centralised and archived knowledge, sharing and diffusion of citizen science data on floods	
			Integrated mathematical models for urban drainage systems, wastewater treatment plants and receiving waters		
			Air model in the sewer system		
			Sediments and litter models in the sewer system		
			Models for life cycle analysis		

Processes, impacts, risks	**Urban flooding**				
	Runoff pollution	Discharges from overflows are probably the key source of environmental impact on stormwater management, and I'd like to see this better reflected.			
		dry-weather pollution management and accumulation -> scientific knowledge and techniques and technologies related with the accumulation of pollutants over urban paved areas during dry weather periods			
		Develop knowledge of runoff pollution dynamics and the pollutant movement and establishment of the pollutograph in water flowing through statistically based methodologies	Integrated Stormwater Management: Support for biodiversity -> impact (diffuse pollution)		
		Pollution from concentrated discharges to be proven			
		Study the potential polluting effect of plastic materials that are suggested for infiltrating stormwater from parking spaces			
Urban services/planning	**Waterwise Cities**	Urban services and the water cycle seem to me to be the most important because they require work on the scale of the city (work on technical objects does not necessarily involve it). On these two needs, it seems to me that there are needs on the whole chain of knowledge production from the scientific work to the transfer.			
		Social science research: communication and acceptability/support for change (2x)	To make evolve the standards of the building industry	Behavioural science: How do you run an advertising campaign to encourage individuals to do integrated stormwater management? For example: a campaign to have all individuals cut out their gutters. How to communicate on stormwater without scaring, what kind of incentives?	

Water Cycle	Water resources	Receiving waters impact in wet weather					Educational sheets to raise awareness among the general public	
		Integrated water supply and underground waters with urban drainage systems to understand infiltration or exfiltration problems						
	Adaptation to climate change	Urban services and the water cycle seem to me to be the most important because they require work on the scale of the city (work on technical objects does not necessarily involve it). On these two needs, it seems to me that there are needs on the whole chain of knowledge production from the scientific work to the transfer.						
		We need to build or improve the sewerage system today for tomorrow's climatic events. We must be able to anticipate changes in order to be able to propose sustainable urban water management. Even before asking the question on how to do this technically, it seems crucial to me to define the objectives to be achieved and therefore to better understand how cities will respond to post-climate change rainfall events.					Educational sheets to raise awareness among the general public	
		Knowledge of tomorrow's rainfall and hazards? -> risks?						
Other topics					Cross-functional project management process: how many people to bring to the table?			
Legend		Fields in blue: suggestions of RI users were assigned to this field		Fields in yellow: suggestions of participants of Rennes workshop	Fields with no colour background: RI users suggested this field specifically for their entry			