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European stakeholders' visions and needs for stormwater in future urban drainage systems

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ABSTRACT

Transitioning urban drainage systems to serve water-smart societies requires the involvement of different disciplines and stakeholders. However, stakeholders have different visions and needs from the transitioning process (e.g in terms of financing, policy adaptation and system management) these also vary between regions and countries. Identifying such different needs for stakeholders is necessary to propose practical adaptation strategies. Therefore, evidence of needs as reflected in policy papers and legislation in seven European countries was collected. Knowledgeable individuals in the urban drainage community were asked about their visions. Results show that whilst there is consensus on the challenges, visions on how to transition are diverse, indicating that more interaction between the different stakeholder groups is required to develop consensus. Additionally, organisational and legislative structures often slow down the necessary change processes.

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Introduction

Since the 1990s, a transition from discrete examples of blue-green infrastructure to a holistic approach of integrating stormwater into the urban environment has been ongoing to restore water cycles, to meet major societal and climatic challenges and to make cities more liveable (Bertrand-Krajewski 2021). Challenges include demographic change, deteriorating infrastructure, urbanisation, a desire for sustainable approaches, and the climate crisis. While the urban drainage sector is not often a major focus of the public domain or policy-makers, framework documents on future needs within the water sector have been published by non-governmental organisations (NGOs) such as Water Europe and knowledge generation organisations such as 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 2021) target more globally the European water sector with a focus on the implementation of innovations. In these publications, a future is envisioned in which the 'conflicts' generated by these major challenges can be addressed by a 'water-smart society' (Water Europe 2016) or, by 'water-wise behaviour' (IWA 2016).

IWA and Water Europe use similar concepts to define available water resources in the urban context, and include surface waters, groundwater, polluted water and stormwater. In the IWA nomenclature, these are described as 'Sustainable Urban Water', whereas Water Europe uses the term 'Multiple Waters'. However, 'Multiple Waters' can contain pollutants since brackish and saline water, brines and used water belong to them, while 'Sustainable Urban Water' has undergone treatment ('desalinated water', 'recycled water'). The proposed approaches to reach a water-smart society that relies on water-wise behaviour can be summarised as (IWA 2016; Water Europe 2016; Water Europe SIRA 2016):

- Taking the true value of water into account by encouraging a circular economy for water and valorising resources such as nutrients and energy from water. This should also enable the development of economically relevant new markets.
- Encouraging the development of new digital technologies to ensure the most efficient use of all waters.
- Developing 'a hybrid grey and green water infrastructure' (Water Europe SIRA 2016; Water Europe 2022) by integrating nature-based solutions (NBS) with traditional infrastructure in centralised and de-centralised solutions while

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respecting a circular economy approach, to benefit from eco-systemic services.

- Implementing new governance structures to promote collaboration for better planning by creating cohesion between urban actors (from the expert to the citizen) and interactions between territories to enable synergies.

This holistic view should encourage innovation, research and development of new digital technologies and NBS to move towards a more sustainable and resilient system aligned with current social and societal needs (Water Europe SIRA 2016).

However, the different disciplines and stakeholders involved in this development, academic researchers, industries, small and medium enterprises (SMEs), NGOs 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.

Only if these visions and needs are collected and understood, connections and conflicts between stakeholders can be identified and adaptation strategies proposed in order to support the transition of Urban Drainage Systems (UDS) within Europe. As, e.g., Blumensaat et al. (2019) pointed out, technological development needs to follow a discussion of its uses and goals if its full potential and value for society can be attained. Applying a transition theory-based approach, Wihlborg, Sörensen, and Olsson (2019) identified 'barriers' and 'drivers' of changing from traditional pipe-bound to blue-green infrastructure in structured interviews in two Swedish municipalities. Based on this assessment, suggestions for changes in the local stormwater management were developed.

These examples show how important it is to identify the connections and conflicts between stakeholders and to propose adaptation strategies in order to support the transition of UDS within Europe. The aim of this paper is to present the results of an evaluation of the visions of different stakeholders for the future of UDS. This evaluation does not claim to be representative; however, the aim of this work is to identify and examine areas where stakeholders express needs to be fulfilled to enable this transition.

Methods

Collaborative Urban Drainage research labs communities – Co-UDlabs[1] is an EU-funded project aiming to integrate research and innovation activities in the field of UDS to address contemporary public health and flood risks and environmental impacts. It is a transnational research and innovation 'starting community', with the aim to influence European regulations and practices to deliver a more sustainable management for UDS in the face of climate change and ageing of grey drainage infrastructure. In order to identify the above-mentioned connections and conflicts between stakeholders and to propose adaptation strategies, three different sources were consulted: (i) public documents from governmental and non-governmental institutions, which define or are related to a 'roadmap' towards transitioning to a water smart society; (ii) opinions of the researchers involved in Co-UDlabs and (iii) opinions from individuals interested in using the research infrastructures (RIs) as offered by the Co-UDlabs project. The information gathered was used as described below.

Development of an evaluation grid

A tabulated evaluation grid was developed. This evaluation grid contains need-based criteria:

(i) Scientific Knowledge,
(ii) Techniques and Technologies,
(iii) Non-technical Solutions, and
(iv) Knowledge Transfer/Training of Practitioners,

and categories dealing with

(i) Technical Objects with subcategories Performance/Asset deterioration/Digital water solutions,
(ii) Processes, Impacts and Risks with the subcategories Urban flooding/Runoff pollution,
(iii) Urban Services and Urban Planning – Waterwise Cities, and
(iv) Water Cycle with the subcategories Water resources/Adaptation to climate change.

Table S1 (Supplementary material) shows the resulting evaluation grid.

Evaluation of national 'roadmaps'

The Co-UDlabs consortium comprises members from seven European countries (Denmark, France, Germany, Spain, the Netherlands, Switzerland and the United Kingdom (UK)). For each country, we studied legal and policy documents with respect to the status and future development of UDS. In total, 8 to 25 documents per country were assessed regarding information on planned or envisioned future development, as well as a description of current shortcomings. Finally, information from 7 (Denmark), 8 (France), 2 (Germany), 9 (Netherlands), 8 (Spain), 11 (Switzerland) and 8 (UK) documents were sorted into the different fields of the above-described evaluation grid. Additionally, the relevant governmental and non-governmental structures were described.

After comparing the entries, those with a similar content occurring in different countries were merged. This resulted in a number for countries per field, which represent the number of countries in which needs were identified and assigned to the respective field. The number of entries per field represents the total number of needs identified, and the number of ideas represents the number of needs remaining after merging similar entries. To allow for a comparison, an 'agreement rate' was calculated: If all entries in a field expressed the same need and, therefore, resulted in one idea, it corresponds to an agreement rate of 100%; if none of these entries expressed the same need, the agreement rate was 0%. If several entries could be reduced to a lower number of ideas since some of the needs expressed were similar, this resulted in

$$agreement\ rate(\%) = 1 - \frac{number\ of\ ideas}{number\ of\ entries} \cdot 100$$

Co-UDlabs perspectives

In order to assess the visions and needs expressed by the scientists involved in the Co-UDlabs project, two sources were used: the first one was the project proposal, the second one was a public consultation for a revision of the Urban Wastewater Treatment Directive (UWWTD) in 2021.

The project proposal was screened according to the criteria and categories of the evaluation grid, and identified needs and visions were recorded as keywords in an evaluation grid dedicated to the Co-UDlabs project visions.

Regarding the survey on the revision of the UWWTD, Co-UDlabs project participants from UDC (University, Spain), GRAIE (one individual, non-profit organisation, France), INSA de Lyon (one individual, Higher Education and research institution, France), EAWAG (expert panel, research institution, Switzerland), Sheffield University (UK) and IKT (non-profit organization, Germany) registered their answers and free comments to the consultation. More details on the respondents are provided in Figure S1 (supplementary materials). From these answers, needs and visions were as well identified and keywords included into the Co-UDlabs evaluation grid (Table S4, supplementary material).

A quantitative summary was then performed in an evaluation grid (Table S3, supplementary material). If a topic was treated in the Co-UDlabs proposal, it was counted once irrespective of how many times it was named in the proposal. Responses resulting from the survey on the revision of the UWWTD were counted individually, as well as the number of comments provided on each topic of the same survey.

Identification of needs by the users of research infrastructure

A central role in transitioning to more sustainable urban water management is apparent in the focus group targeted by the Co-UDlabs project due to their potential interest in using the available RI platforms. This group consists of people from SMEs, industry, engineering consultancies, but also academic research groups without their own RI or actors in public service with legal responsibilities in the field of urban drainage. To get their opinions of future developments in urban drainage, we developed a survey (see Questionnaire, supplementary material) based on the needs and vision assessment from the national roadmaps and the Co-UDlabs participants. Within the survey, the respondents were asked to position themselves in the evaluation grid resulting from the analysis of the national roadmaps and the Co-UDlabs' perspectives, and to express any additional needs. The survey was placed online, and the seven Co-UDlabs partners with RI invited contacts from their networks to participate. Twelve people filled out the survey online; background information can be found in Figure S2, supplementary materials.

The survey was also presented during a conference in Rennes, France, in June 2022 ('Carrefour des gestions locales de l'eau de Rennes'), and ~25 participants, mostly from public water utilities and municipalities, were asked to write down their anticipated needs and add it via post-its to a poster presenting the evaluation grid. Approximately 20 participants provided feedback. The needs expressed in the online survey and the post-its from the Rennes workshop were transferred into keywords in a combined evaluation grid (Table S5, supplementary material).

Results

Evaluation of national 'roadmaps'

Denmark

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 organisation, which are all responsible for providing drinking water, effective drainage and efficient wastewater treatment. On the national level, the Ministry of Environment and Food is responsible for environmental regulation, while the Ministry of Energy, Utilities and Climate regulates economic issues of the sector. At the local level, 98 municipalities are responsible for water and environment, including production of 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 to create a more efficient water sector since it was difficult to separate the economic interactions between utilities and municipalities, and the parliament feared that the total costs of water for the consumer were unreasonably high. Hence, the utilities were legally and economically separated from the municipalities following a new principle that no utility should be able to generate a profit from their activity.[2] Consequently, all utilities undergo benchmarking every year to set a price for water supply – and thereby for activities of wastewater treatment, rainwater management and climate adaptation.

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. The impact of climate change is stressing existing UDS, increasing the risk of flooding and the frequency of combined sewer overflows (CSOs). At the same time, increased public awareness of the environment demands reduction of the adverse impacts from urban areas. This has created a desire to quantify the amount and composition of CSOs on a national scale.

In recent years, several water utility companies in Denmark have experienced that stormwater runoff from urban areas has started to vary significantly depending on seasons. The Danish winters have become wetter with more rainfall than previously. Consequently, the soil tends to become more saturated during winter and increases the active stormwater runoff by including semi-permeable and permeable surfaces, where rainfall normally infiltrates. This has generated a focus on methods, measurements and models that can predict location- and event-specific runoff.

France

One of the major regulatory difficulties for stormwater management in France is its complexity: many national and local regulations exist, many documents (mostly regulations and guidelines) are available to territorial actors to manage stormwater in a sustainable way, and it is difficult for a non-specialist to get an overview.

Spatial planning is a fundamental lever for limiting water-related impacts and risks, and for adapting to climate change. In France, a recently enacted law contains the goal of reducing the net land consumption (for housing and economic development) to zero by 2050[3] by halving it every decade, while at the same time prioritising the infiltration and evaporation of rainwater.

In terms of water policy, in 2015, the NOTRe law[4] established a new specific competence, the GEPU – Gestion des Eaux Pluviales Urbaines[5] (Urban Stormwater Management), and helped evolve the distribution of drinking water and sanitation obligations by moving them from single municipalities to groups of municipalities, implying a mutualisation of technical competences. In 2015, more than 33,000 utilities were dedicated to drinking water or drainage system management,[6] this number had decreased to 26,000 in 2020.[7]

At the same time, the General Council for the Environment 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. Additionally, 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.

Regulatory developments are converging towards 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), included in an action plan for 2022–2024 by the Ministry of Ecological Transition. It proposes a set of concrete actions reflected in four thematic areas: (i) integrating stormwater into development, (ii) raising awareness of the challenges and benefits of managing rainwater at source, (iii) facilitating urban stormwater governance and policing and (iv) improving scientific knowledge. Details on this action plan can be found in Supplementary materials.

Germany

The federal structure of Germany is reflected in 'The Federal Water Resources Act' (WHG, 2009), which transposes the requirements of the EU Water Framework Directive (WFD) into national law. This act also defines general requirements for wastewater disposal. The water laws and ordinances of the 16 federal states supplement and enforce federal water legislation.

Water legislation is implemented at the municipal level, which is responsible for wastewater disposal, organised by municipal wastewater utilities or wastewater associations of several municipalities.

Due to the decentralised and also very localised organisation of German wastewater and stormwater disposal, close cooperation between the stakeholders involved is needed. However, implementing SUDS can be difficult at the municipal level since several departments have to be involved, such as wastewater utilities, spatial planning, road and civil engineering, property owners, and supervisory authorities.

In June 2021, a draft version of a National Water Strategy of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety was published (BMU 2021). However, this draft is only a basis for further discussions in Germany. Fundamental challenges are the increasing pressure on water as a resource and issues, such as (i) climate change (droughts and heavy rainfall), (ii) changes in environmental policy to reduce pollution of waterbodies by nitrate, phosphorus and a multitude of other substances and (iii) developments such as digitalisation, changes in lifestyle and land use.

In general, 10 strategic themes are stated for water management: (i) Strengthening awareness of water as a resource; (ii) further developing water infrastructures; (iii) linking water, energy and material cycles; (iv) limiting risks from substance inputs; (v) restoring and managing the natural water balance – preventing conflicting objectives; (vi) implementing water-compatible and climate-adapted land use in urban and rural areas; (vii) further developing sustainable water management; (viii) protecting marine areas (North Sea and the Baltic Sea) more intensively against discharges from the land; (ix) strengthening efficient administrations, improving data flows, optimising regulatory frameworks and securing funding and (x) protecting global water resources sustainably together (BMU 2021).

Netherlands

In the Netherlands, the national directorate for public works and water management 'Rijkswaterstaat' has the responsibility for water quantity and quality of Dutch rivers, canals and large waterbodies such as the IJsselmeer. Twenty-one public waterboards are responsible for managing regional waterbodies. With the expected increase in rainfall peak intensities due to climate change, simply increasing the capacity of existing systems will not ensure sufficient flood protection or acceptable environmental protection levels.

Another important driver for policymaking is the concept of sustainability: e.g. when a municipality plans new developments, it needs to choose a system for urban drainage that enables (i) the reuse of water, (ii) keeping various 'streams' separated using separate sewer systems unless they are financially or economically not feasible and (iii) keeping stormwater 'on site' to avoid local drought and subsidence.

A very important development is that asset management of UDS has gained more attention over the past 30 years. Regular inspections, rehabilitation and replacement plans are drafted on a regular basis by municipalities.

National authorities, waterboards and municipalities need to co-operate to implement the overarching policy as described and work out plans on a detailed level. In the National Water Program (cNWP), the need for knowledge development is identified as a crucial prerequisite to achieve these goals. With new legislation ('omgevingswet'[8]) additional responsibilities are to be given to local authorities (municipalities to implement solutions and the waterboards to enforce local policy) to enable tailor-made locally appropriate solutions. Since the responsibilities are given to local authorities, the national authorities formulated a strategic framework on a highly abstract level only.

According to the latest progress report, by 2027, it is expected that national waterbodies (e.g. large rivers) will comply with the goals set by the EU WFD, while for regional waterbodies, this compliance accounts only for 35–65% of these waterbodies. Further improving their ecological quality implies, among other measures, 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 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.

Given the hydrological situation of the Netherlands, tuning policymaking and implementation of policies with other European countries (specifically, Belgium and Germany) are crucial. Co-operation between these entities requires monitoring for which a rather complex system of legislation, policymaking, asset management plans, detailed action plans and long-term agendas are being drafted (cNWP 2022).

Spain

The current Spanish Water Act has been in force since 1985 and presents the legal framework for water quantity, use, protection, and planning for all Spanish river basins. The current text does not contain any specific aspects on stormwater or urban drainage management.

The urban water sector is very fragmented. Water supply, urban drainage and wastewater treatment are managed by the different councils and metropolitan areas according to dozens of regulations at national, regional and municipal level. In some cases, the water services are managed using an integrated approach, especially in large cities and metropolitan areas, but usually, services are divided among several entities and water operators. Regarding wastewater and stormwater transport and treatment, a harmonised governance scheme is missing, and the River Basin District approach as requested by the EU WFD is not applied in most of the large urban agglomerations in which different councils are involved. Design criteria and management practices vary across the country, and even within the same River Basin Districts.

Regarding the normative framework, after the transposition of EU UWWTD, the most relevant milestone in Spanish urban drainage was the modification in 2012 of the Regulation of Water Act, which established permits for spills to waterbodies. From this date, the management of CSOs during rain events is considered in the regulatory framework. The law requires the Ministry of Environment to establish national guidelines defining 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 since 2012.

In 2016, a modification of the Spanish regulations for the public sector, which introduces urban risk management, states that new industrial and urban developments must implement SUDS to reduce the risk of flooding (Ministerio para la Transición Ecológica 2019; Andrés-Domenech et al. 2022). This national framework provides general rules for regional and local governments to develop their own regulations.

The main challenges for the water sector are defined in the Spanish Green Book of Governance (Gobierno de España 2020). These are (i) adapting the current regulatory framework; (ii) strengthening the organisational and financial structures of the water sector; (iii) improving the coordination and cooperation among the different administration levels; (iv) improving (evidence-based) decision-making, water digitalisation and water knowledge and (v) implementing 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' opinions. Urban flooding and pollution impacts related to weather events must be included in the analysis of urban water systems. NBS are being promoted. Furthermore, the publication also states the main economy-scale problems, which do not allow small municipalities to provide services at reasonable costs nor to establish control of sufficient service quality. This has led to the outsourcing of service to private water utilities, which has meant, in most cases, the loss of water management information.

The 'Spanish Urban Agenda' (Ministerio de Fomento 2018) defines 30 strategic actions aligned with SDGs and 2030 Agenda (UN 2015), including the main objectives for the field of urban drainage, i.e. to prevent and mitigate climate change impacts, to improve urban resilience, to enhance sustainable resource management and to favour a circular economy approach.

Switzerland

The Federal Office of the Environment (BAFU) is the most important actor on the federal level in Switzerland and defines the requirements for water quality. The Water Protection Act specifies the locations where wastewater must be treated and disposed of. The cantons, however, are responsible for ensuring that municipalities develop their own General Drainage Plan (GDP), which is a planning instrument for the strategic development of urban drainage infrastructure, which includes different sections such as flood protection, infiltration/inflow, condition assessment and investment planning. The cantons also guide the development of Regional Drainage Plans for larger interconnected systems. 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.

Urban water management is mostly organised by wastewater associations ('Zweckverbände'). Their goal is to collect and treat domestic, commercial and industrial wastewater produced in their catchment area. Typically, the associations operate a central WWTP on behalf of several municipalities. Often, they operate the main collectors as well, and ancillary structures, such as pumping stations or CSO tanks. However, the latter can also be operated by the municipalities.

As Switzerland is rather fragmented (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 organise other tasks, such as the supply of drinking water and protection against flooding. This also means that water issues are dealt with in a wide number of different cantonal laws and ordinances.

An integrated national strategy for urban stormwater management is lacking in Switzerland. However, we identified three major studies, which provide detailed advice to address current and future challenges.

The synthesis report 'Wastewater Management 2025' (EAWAG 2012) includes 'recommendations for action', for which different stakeholders are responsible. They include measures (i) for improving infrastructure management by reducing the heterogeneity and organisational fragmentation; (ii) that improve and promote integrated catchment management actions; (iii) that guarantee the safe and optimal drainage of storm- and wastewater from the settlement area; (iv) to create synergies at supra-regional or national level and (v) that directly benefit or improve the water quality of surface or groundwater, such as better understanding the impact of wastewater exfiltration on waterbodies.

'Heat in cities' (BAFU 2018) emphasises that climate change will lead to more frequent and longer periods of hot weather. The study 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 the supply of fresh air from the surrounding area and air circulation in the city.

'Stormwater in settlements' (BAFU 2022) emphasizes the potential of the 'sponge city concept' and concludes that an important factor for success is the transdisciplinary cooperation of the different actors. Those responsible for urban drainage and for flood protection, experts from the fields of urban planning and development, and from architecture and landscape planning, building owners, political actors, etc., must all work together to develop and implement solutions. The study lists specific instruments that are already implemented and allows for a 'good handling' of stormwater to ensure a 'near-natural' urban water cycle by infiltrating unpolluted rainwater and by discharging mildly polluted rainwater into surface waterbodies (AWEL 2022).

To translate the high-level conceptual studies into actionable information and standards, the Swiss association for wastewater professionals ('Verband Schweizerischer Abwasser- und Gewässerschutzfachleute', VSA) and other professional associations are currently developing several guidelines or recommendations.

United Kingdom

The UK water sector is fragmented with a range of organisations holding different responsibilities in terms of the provision of effective drainage, treatment of wastewater, and the protection of the environment. Water supply, collecting and treating wastewater, and providing 'effective' drainage are organised by a small number of catchment-based private water and sewerage companies (WaSCs). However, this applies only in England, while there are different regulatory and political structures in Scotland, Wales and Northern Ireland.

The WaSCs resulted from a decision of the UK government in the early 1990s to privatise the public Regional Water Authorities and to issue 25-year licenses to private companies within a designated river basin catchment due to under-investment in water-related infrastructure for decades. The private companies were to raise investment funds, resulting in the nine largest UK water companies currently having approx. over £50Bn debt that has funded infrastructure investment since privatisation.

Since these companies (with shareholders) are effectively regional monopolies of an essential service, the government created a framework of strict regulation overseen by the Drinking Water Inspectorate,[9] the Water Services Regulation Authority (OFWAT),[10] and the Environment Agency (EA).[11] The last two regulators significantly influence the management of UDS. OFWAT's purpose is to ensure water company shareholders get a fair return on their investment and that customer charges are controlled. OFWAT benchmarks companies, so that customer charges are 'value for money'. The EA as environmental regulator has a duty to ensure that water companies do not cause significant impact on the environment. It regulates the management of CSOs and pollution of groundwater sources and also has a role in managing river flood risk. All three regulators have oversight from the Department of Food and Rural Affairs (DEFRA), a central government ministry. DEFRA has historically not been pro-active, but, recently, it has intervened directly, for example, requiring the event duration monitoring of practically all storm overflows since 2013. These open data have generated significant public concern resulting in the recent creation of a Storm Overflow Taskforce. In combination with the recently enacted Environment Act,[12] which places significant new obligations on water companies in the field of urban drainage, it has been indicated that there will be much stricter control of pollution impacts of UDS on the receiving waters. The Environment Act forces WaSCs to agree spill reduction targets with the government and also to install upstream and downstream water quality monitoring on all storm sewer overflows operated by WaSCs. The implementation timescale is by the mid-2030s.

The UK structure has resulted in a number of NGOs that interact with the WaSCs, such as WaterUK[13] and UK Water Industry Research[14] (UKWIR).

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 on main rivers. It has led to a number of initiatives from different parties to develop roadmaps that do not have statutory backing. In addition to the aforementioned Storm Sewer Overflow Taskforce set up by DEFRA, two initiatives will be considered here:

(1) In 2019, UKWIR started a 'Big Question' program. This was a series of road mapping projects that examined the 12 big questions facing the UK water sector. These projects involved strong engagement with different players and structured assessment of the different pressures that may emerge over a timescale up to 2050. The UKWIR road mapping projects developed a program of potential R&D projects structured in terms of short-, medium- and long-term needs.
(2) The growing public mistrust in the private WaSCs has led to demands for legislation to obligate collaborate work and higher levels of transparency. Drainage and Wastewater Management Plans (DWMPs) are now a legal requirement under the Environment Act. 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: (i) capacity assessment frameworks, (ii) storm overflow assessment frameworks and (iii) wastewater resilience metrics to better structure wastewater and drainage planning.[15]

Summary of the revised policies

The organisation and legislative structure of stormwater management and treatment in the seven countries represented here 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 been structured and implemented results in different degrees of competences and interdependences at a local level. 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. The management of stormwater and the implementation of SUDS are 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 of these tasks. Varying legislation in the administrative divisions (e.g. the 16 states in Germany, 17 autonomous communities and two 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 required change towards more 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 the United Kingdom: plans specifically dedicated to sustainable stormwater management and overflow reduction (Action Plan 2022–2024 in France/Storm Overflow Discharge Reduction Program in UK).
- Switzerland: integrated national strategy is still missing, but the three described reports on wastewater management, heat in cities and extreme events/stormwater management point to the direction such a strategy could take.

Focus of roadmaps with respect to the evaluation grid

The quantitative analysis of the needs identified for the different countries with the evaluation grids described in the Methods section showed a large heterogeneity of the expressed needs, which is reflected in the summary Table 1, and the detailed entries of the evaluation grid provided in Table S2 (Supplementary material). The only field where more than one country (three in total) identified the same need (= 100% agreement) is 'Technical objects – Assets deterioration/ Knowledge transfer'. The need expressed was 'to train professionals to improve self-monitoring, knowledge of the state of the works and critical thinking' in the analysed documents of France, Switzerland and the Netherlands. This was also the subcategory with the highest overall agreement. Among eight entries in 'Scientific knowledge', the ideas 'Improve the knowledge on pipe deterioration', 'Improve the knowledge on NBS medium- to long-term performance' and 'Data-driven models to failure of assets' were suggested by two countries each (37.5% agreement), and for 'Techniques and technologies', two out of four entries described 'Measuring and data analysis for all infrastructure' (25% agreement). However, common interest was limited with an average of 3.5 countries per criterion (average number of all rows for this column). The subcategory with the maximum number of entries in the revised policies is 'Runoff pollution' within 'Processes, impacts, risks' with an average of five countries expressing needs for the different criteria and an agreement of:

- Twenty-nine per cent for 'Scientific knowledge': 17 entries resulting in 12 ideas, topics linked to 'Monitoring of contaminants and pollution sources' formulated in three national roadmaps, and 'Knowledge on emerging contaminants', 'Microbial pollution in surface waters' and 'Development of predictive/detailed models' in two national roadmaps each.
- Twenty-seven per cent for 'Techniques and technologies': 11 entries resulting in 8 ideas, topics linked to 'Metrology: to improve discharge monitoring and data management' formulated in three national roadmaps, and '(Pollution-based) RTC control' in two.
- Thirty-three per cent for 'Non-technical solutions': six entries resulting in four ideas, with the topic 'Unified taxation for discharge of nutrients from stormwater outlets and CSO' found in three national roadmaps.

The topic 'Runoff pollution' also received overall the highest number of entries, on average 9.25 entries resulting in an average of 6.5 needs expressed per criterion. The second highest global interest was expressed for 'Technical objects – Performance' with an average of 4.25 countries, 8 entries and 6.5 ideas, respectively. Common topics here were for 'Scientific knowledge' (10 entries resulting in 6 ideas) 'Data driven modelling with AI to develop system knowledge' (3 countries), 'Data quality of available performance monitoring data' and 'RTC control/Remote sensing' (2 countries, respectively).

Evaluation of Co-UDlabs perspectives

The Co-UDlabs perspective was obtained from the response of six project participants to the survey on the revision of the UWWTD and needs formulated in the project proposal. With respect to the survey, the project partners believe in line with the objectives of Co-UDlabs that the most important topics of the regulatory review are integrated approaches to better manage stormwater overflows and urban runoff. All six individuals gave the highest importance to using NBS in urban wastewater management whenever possible.

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

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

A quantitative overview is presented in Table S3; all weighted answers to the UWWTD survey and the additional comments can be found in Table S4 (Supplementary material).

The entries resulting from the Co-UDlabs project description emphasise the column '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 most of the 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 digital technologies and improve their use on all levels, which is also a strong focus of the Co-UDlabs project.

The single categories receiving the highest interest were 'Urban services, urban planning – Waterwise Cities' and 'Non-technical solutions' (six 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;
- Including 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; and
- Incentives to improve monitoring and data quality.

'Processes, impacts, risks – Runoff pollution' received five comments for 'Non-technical solutions', which also target 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.

Identification of needs by the users of research infrastructure

In the first part of the survey, the participants were asked whether they agreed with the selected criteria and categories, which was the case for most respondents. The detailed feedback can be found in Supplementary materials (Table S5).

In the second part of the survey, the participants were asked to position themselves to the presented evaluation. Three participants criticised that the focus from the national roadmaps as well as from the Co-UDlabs project summarised in Table Q4 (Supplementary materia) was too strongly placed on 'Technical objects' and 'Processes, impacts, risks', while one participant mentioned that he or she especially agreed with this emphasis.

When being asked which specific needs the participants see for the different criteria, there were two types of responses: while one group named the field or criteria they considered most important, the other made concrete suggestions (shown in Table S5, Supplementary material). Overall, the most comments (7) were made concerning 'Technical Objects – Performance', with four for the criterion 'Techniques and technologies', targeting three different topics: creating structures for stormwater recovery and reuse for events with high return frequencies; promoting pollutant removal and focusing on infiltration parameters. This criterion also received the most feedback for 'Digital water solutions' (five needs in total for this subcategory) with suggestions for integrated models of urban drainage systems, wastewater treatment plants and receiving waters, models for sewer systems (air and sediments) and life cycle analysis. Also, five entries were made for 'Processes, impacts, risks – Runoff pollution' with the majority dedicated to 'Scientific knowledge'. Here, increased knowledge on dry weather pollution management and accumulation during dry periods, runoff pollution dynamics and polluting effect of infiltrating microplastic materials was requested.

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 being highlighted for each category in the proposed framework. However, looking at the different propositions some can be summarised. Table 2 gives an overview of the different sources per topic. A need had to be mentioned at least twice by different initiators to be included. The following topics were identified:

'Technical objects'

For the subcategory 'Performances', by far the most interest was on more 'Scientific knowledge', and specifically on data collection, data quality and the use of data in modelling. Three other common topics resulting from the analysis were related to (i) the evaluation of maintenance and long-term evolution of urban drainage assets; (ii) the standardisation of the assessment of UDS performances and (iii) the treatment of highly variable wastewater flows impacted by stormwater.

For all other criteria of this subcategory, a variety of suggestions with only few overlaps were made. To be named here are for 'Techniques and technologies' the identification of sewer infiltration, adaptation of sewer systems and soil infiltration, and 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'.

The entries for 'Assets deterioration' subcategory resulted for 'Scientific knowledge' in three main groups: (i) research on sewer processes leading to corrosion; (ii) long-term performance and resilience of UDS and NBS and (iii) the use of 'big data', especially for modelling.

Data collection and analysis were highlighted in the 'Techniques and technologies' criterion. Even 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 a consistent need.

In 'Digital water solutions', three topics were commonly named for both 'Scientific knowledge' and 'Techniques and technologies' across all sources. These include (i) advanced monitoring, such as the use of interconnected smart monitoring techniques; (ii) improved data management and evaluation, e.g. through data harmonisation and sharing and (iii) 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 popular 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.

Table 1. Needs expressed in the legislation and policy documents of Denmark, France, Germany, Spain, Switzerland, the Netherlands and the 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

1 country, 1 entry, 1 idea

- 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.
- The number of different ideas in the right circle reflects the total number of needs expressed in all roadmaps.
- 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.

'Processes, impacts, risks'

The subcategory 'Urban flooding' is uniquely covered by the national 'roadmaps'. 'Scientific knowledge' and 'Techniques and technologies' are mainly requested for predictive models and risk maps, which are 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.

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. For example, more 'Scientific knowledge' is requested for (i) monitoring of contaminants, and pollutant sources, especially with regard to the quality of the obtained data; (ii) the impact of pollutants on the environment, e.g. on surface waters, groundwater or the soil used for infiltration; (iii) the dynamics of pollutant accumulation and transport and (iv) 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 (i) financial aspects: for example, unified taxation for nutrient discharge from stormwater outlets and CSOs and better application of the 'polluter pays' principle and (iii) developing an integrated planning for stormwater. Lastly, training on metrology was the only common point named for 'Knowledge transfer and training of practitioners'.

'Urban Services, urban planning - Waterwise cities'

The needs pointed out for 'Scientific knowledge' showed no agreement; five out of the seven different entries can be found in the various national 'roadmaps' (Table S3). Development of design approaches and strategies for urban planning, including the evolution of standards for the building industry was the most addressed topic in 'Techniques and technologies'.

'Non-technical solutions' was the criteria that received the most entries, with three identified topics: (i) governance structure on different levels: necessity of implementing clear structures between the different stakeholders and holistic planning in urban planning by establishing frameworks and open policies; (ii) local responsibilities: allow local operators to develop their own action plans, e.g. by also strengthening inter-municipal cooperation and (iii) 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' identified three topics: (i) develop tailored training activities, especially on stormwater management, for different stakeholders; (ii) create an overview of available research infrastructures and enable access and network creation and (iii) provide information for the public.

'Water cycle'

In the subcategory 'Water Resources', the entries for developing 'Scientific knowledge' resulted in two main groups: (i) the impact of wet weather discharges on receiving water and (ii) the 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'.

Only two criteria resulted in corresponding needs for 'Adaptation to climate change', 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 ('Techniques and technologies').

Discussion and conclusions

Overall, the evaluation shows that the particular needs for UDS identified by the different stakeholders are diverse and cannot be limited to major axes. The fact that numerous needs were identified indicates the level of effort that is still needed for transitioning to sustainable urban drainage systems to be achieved and that whilst there is consensus on the challenges there is no clear agreement on the exact transition pathway or pathways to follow.

Only a small number of the needs were identified by the three sources: national roadmaps, Co-UDlabs participants and (potential) RI users (Table 2). While this is also due to the limited number of responses from the RI users, it could also indicate that more interaction between the different stakeholder groups is necessary to develop consensus, but the sample size in our study is too limited for a definite conclusion. In a review article by Qiao, Kristoffersson, and Randrup (2018), the authors tried to identify the challenges linked to the implementation of urban sustainable stormwater management. Unclear leadership and responsibilities, governance arrangements and a lack of private stakeholder participation (in the sense of participation of individual households) were considered to hinder such a transition. While other than the private stakeholders in the review, the RI-users included in the Co-UDlabs project are well informed of the necessary changes in the stormwater sector, transversal communication between the different involved groups does not seem to be sufficient at this point. In a study in Sweden (Bohman, Glaas, and Karlson 2020), where workshops between urban planners, government officials and water utilities were held to identify the major problems hindering sustainable stormwater management in urban planning, it was pointed out that a real collaboration between the different involved stakeholders is often lacking, which slows down the development of a common vision.

Shortcomings of maintenance and assessment of UDS performance have been critically discussed in the urban drainage community over the last two decades (Langeveld et al. 2022); our evaluation shows that transfer into practice of improved approaches is limited.

Some of the identified needs are in line with the visionary documents of IWA and Water Europe. It is interesting to see that all questions around (real-time) big data management and

Table 2. 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	●●○○○○ ○○○○○○ ○○○○○○
		Maintenance and long-term evolution	●○○○○○ ○○○○○○ ●○○○○○	Adaption of sewer systems	○○○○○○ ○○○○○○ ●●○○○○	Multi-stakeholder gouvernance	●●○○○○ ○○○○○○ ○○○○○○	Network creation	●●○○○○ ○○○○○○ ○○○○○○
		Standardise assessment	●○○○○○ ●○○○○○ ○○○○○○	Soil infiltration	○○○○○○ ○○○○○○ ●●○○○○				
		Treatment of highly variable flows	●○○○○○ ●○○○○○ ○○○○○○						
	Assets deterioration	Sewer processes	●●○○○○ ○○○○○○ ●●○○○○	Data collection and analysis	●●●○○○ ○○○○○○ ○○○○○○	Management of assets	●●○○○○ ○○○○○○ ●●○○○○	Training of professionals	●●●○○○ ○○○○○○ ○○○○○○
		Performance and resilience	●●○○○○ ●○○○○○ ○○○○○○			Costs and investment	●●○○○○ ○○○○○○ ○○○○○○		
		Big data	●●○○○○ ○○○○○○ ○○○○○○						
	Digital water solution	Advanced monitoring	●●●○○○ ●●○○○○ ●○○○○○	Advanced monitoring	●●●○○○ ●○○○○○ ○○○○○○	Citizen involvement	●○○○○○ ●●●○○○ ●○○○○○	Training for monitoring devices	●●●○○○ ●●○○○○ ○○○○○○
		Data management and modelling	●●○○○○ ●○○○○○ ○○○○○○	Data management	●●●○○○ ●○○○○○ ○○○○○○	Organisational issues	●●○○○○ ●●○○○○ ○○○○○○		
				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	●●●○○○ ○○○○○○ ○○○○○○
								Preventative flood management	●●○○○○ ○○○○○○ ○○○○○○
	Runoff pollution	Monitoring of contaminants	●●●●●● ○○○○○○ ○○○○○○	Data collection and model development	●●●●○○ ○○○○○○ ○○○○○○	Financial aspects	●●●○○○ ●○○○○○ ○○○○○○	Training on metrology	●○○○○○ ●●○○○○ ○○○○○○
		Impact of pollutants	●●●○○○ ●○○○○○ ●●○○○○	Runoff management	●○○○○○ ●○○○○○ ●●○○○○	Sustainable stormwater solutions	●○○○○○ ●●○○○○ ○○○○○○		
		Pollutant dynamics	●○○○○○ ●○○○○○ ●●●○○○			Integrated planning	●○○○○○ ●●●○○○ ●○○○○○		
		Modelling	●●○○○○ ○○○○○○ ○○○○○○						
Urban services, urban planning	Waterwise Cities	*No common topic could be identified.*		Design approaches and strategies	●●●○○○ ○○○○○○ ●○○○○○	Governance structure	●●●○○○ ●●○○○○ ○○○○○○	Tailored training activities	●●○○○○ ●●○○○○ ○○○○○○
						Local responsibilities	●○○○○○ ●●●○○○ ○○○○○○	Available research infrastructures	●●○○○○ ●○○○○○ ○○○○○○
						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*	
		Prevention and restoration of surface waters	●●○○○○ ○○○○○○ ○○○○○○						
	Adaptation to climate change	Integrated and holistic models	●●●○○○ ○○○○○○ ○○○○○○	Make technical choices and regulations climate-proof	●○○○○○ ●○○○○○ ○○○○○○	*No common topic could be identified.*		*No common topic could be identified.*	
		Anticipating the effects of global change on existing sewer systems	●○○○○○ ○○○○○○ ●○○○○○						

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

advanced monitoring and training in these technologies were mentioned by different sources. 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 program to shift the European Water System (Water Europe SIRA 2016). This shows that while awareness of the importance of these topics is developing among different stakeholders, concrete actions in many cases still need to follow.

Qiao, Kristoffersson, and Randrup (2018) identified also a lack of funding as an influencing factor for the rate of transition, which might slow down the overall process. High initial investments were also named as hindrance in a study by Forrest, Stein, and Wiek (2020) on transferring from classical sewer to sustainable urban water solutions by upscaling a local pilot project to three major cities.

Blumensaat et al. (2019) assessed future trends associated with ubiquitous sensing in the water sector in a horizontal scanning process. Elements of the 10 identified most emerging topics were addressed in 'Technical Objects – Digital water solutions', especially by naming advanced monitoring. Additionally, one of these trends was coherent with a topic identified for 'Processes, impacts, risks – Runoff pollution': linking aquatic ecology to emissions, i.e. mitigating the impact of pollutants on the environment by new monitoring techniques, integral data sets and harmonised indicator metrics. These topics were identified as highly novel and important, but less familiar (Blumensaat et al. 2019), and the fact that they were named by different parties in our study shows a common awareness of them.

The evaluation of the organisation and legislative structure in the countries represented in our study can also be a source of slowing down innovation in the urban drainage sector; this phenomenon was mentioned in Qiao, Kristoffersson, and Randrup (2018). The evidence collected in this study shows a high degree of agreement in the challenges and constraints that are faced in the area of stormwater management and that more collaborative and coordinated approaches are needed. Forrest, Stein, and Wiek (2020) name existing regulations or policies as prohibitive or restrictive in terms of implementing sustainable solutions, including rainwater harvesting and greywater reclamation. The analysis of the documents and responses in our study did show that the regulatory and organizational structures put in place to manage stormwater varied considerably, from country to country and even within some countries, e.g. Spain. Some countries manage stormwater at a single municipality level whilst others at a larger scale integrating urban and surrounding rural areas. Confusion over responsibility for stormwater management was mentioned in several countries.

This diversity in approach has happened even with several well-established European directives, such as the Water Framework Directive and the Urban Wastewater Treatment Directive, which are widely thought to be effective. It is clear that many countries have tried to integrate stormwater management into existing governmental structures with a range of success in terms of effective flood risk reduction. Changes in the legislation and organisation of stormwater management are occurring or are proposed in all countries studied; however, it is clear that an 'ideal' approach has not yet been identified. This period of changes offers significant opportunity for comparative studies as new organisational and regulatory structures are introduced. However, more integrated planning of the water sector, which was one of the points mentioned for different criteria and categories, as well as clarifying roles and responsibilities of all actors need to be more strongly implemented.

Highlights

- Visions on how to transition urban drainage systems to serve a water smart society were collected from different stakeholders, policy and legislation documents
- Formulated needs for such a process were diverse and allowed no limitation to major axes
- Comparison with visionary documents of NGOs showed that awareness of solutions exists, but implementation of different measures still lags behind.
- Organisational and legislative structures slow down the transitioning processes.

Notes

1. https://co-udlabs.eu/.
2. https://www.en.kfst.dk/water-regulation/revenue-caps/.
3. https://www.legifrance.gouv.fr/loda/id/JORFTEXT000045197395/ (in French).
4. https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000030985460/ (in French).
5. http://www.graie.org/graie/graiedoc/doc_telech/Graie-CompetenceGestionEauxPluvialesUrbaines-OuvragesMissions-mai19.pdf (in French).
6. https://www.services.eaufrance.fr/docs/synthese/rapports/Rapport_SISPEA_2015_complet_DEF.pdf.
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