Mapping of drivers and barriers for the implementation of cyber-physical water systems

Deliverable 5.4

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Deliverable N°5.4	Mapping of barriers for implementation cyber-physical water systems
Related Work Package	5
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Abstract	D5.4 gives a summary on the drivers, barriers and requirements for transferability and replicability of the 15 digital solutions developed within DWC. In particular, it assesses key operational (e.g. local challenges and management practices, etc.), organizational (e.g. local ICT governance and system interoperability) and technical conditions (e.g. type of network, precipitation pattern, etc.) for a successful implementation of the solution. The results can be used as a checklist for water utilities to assess the potential for local deployment of each digital solution.

Dissemination level of the document

X	PU	Public
	PP	Restricted to other programme participants
	RE	Restricted to a group specified by the consortium
	CO	Confidential, only for members of the consortium

Versioning and contribution history

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1. Introduction

DWC's main goal is to boost the integrated management of water systems in five major European cities – Berlin, Milan, Copenhagen, Paris and Sofia – by leveraging the potential of data and smart digital technologies. 24 partners from 10 European countries will develop and demonstrate the benefits of a panel of innovative digital solutions to address major water-related challenges. These include the protection of human health, the performance and return on investment of water infrastructures and the public involvement in urban water management. DWC further integrates the development of digital solutions in a dedicated guiding protocol to cover the existing gaps regarding governance, interoperability and cybersecurity.

WP1, 2 and 3 focus on the development, demonstration and assessment of the benefits of 15 digital solutions, easily consultable at the website digital-water.city. Approaching the end of the project, each solution is almost fully developed and has already been deployed locally in our five city case studies.

This document aims to **summarize the main drivers, barriers and requirements** for transferability and replicability of the 15 digital solutions developed within DWC. In particular, it assesses key operational (e.g. local challenges and management practices, etc.), organizational (e.g. local ICT governance and system interoperability) and technical conditions (e.g. type of network, precipitation pattern, etc.) for a successful implementation of the solution.

Note that this document does not aim at outlining general requirements for transferability: it focuses on the specific requirements of the 15 digital solutions developed in DWC. The goal is to map the obstacles and drivers regarding the transfer and replication of the digital solutions in other contexts. In other words, if we were to deploy a given solution soon in another city, what shall we consider? The analysis would make possible to anticipate potential factors that could impact or serve the development and implementation of the solutions, as drivers, or on the contrary as barriers, and how to contextualize them locally.

Section 2 introduces the methodology whereas sections 3 and 4 present the outcomes of the transferability study. Section 3 describes the main drivers and obstacles for implementation of each solution. Section 4 presents the specific requirements that would favor or hinder the uptake of each solution in form of factsheets.

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2. Methodology

Following the two transferability workshops organized in 2020, a methodology has been elaborated to analyze the potential of each digital solution. The goal is to map the obstacles, drivers and requirements regarding the transfer and replication of the digital solution in other contexts. The results could be used as a pragmatic checklist for new utilities to assess the potential for local deployment.

The methodology includes the active brainstorming and contribution of all developers (i.e. IPR owner, key technical developers and demo partners) in two steps

- Step 1: the description of the drivers and obstacles for the implementation of each solution.
- Step 2: the description of the specific requirements that would favor or hinder the uptake of each solution.

For step 2, a template has been prepared with partners of WP5 (exploitation) and WP3 (policy and ICT governance) which gathers the main topics when it comes to assess the transferability of the solutions. It includes

- Environmental settings: Local issues, Climate condition, Topography, Type of infrastructure
- Technical settings: Type of network, Asset condition
- Governance and organizational: Teamwork and responsibility, Management practices
- IT settings: Local ICT governance settings; Interoperability requirements; Level of digitalization

A first assessment of the templates with one solution has been done with DS14 (T sensors for CSO emissions) in Autumn 2021. Considering the feedback of the first tester, the templates have been refined and then shared with all developers. The full assessment of all solutions has been prepared by the developers at the beginning of 2022.

Section 3 shows the outcomes of the survey for step 1 (description of the main drivers and obstacles for implementation of each solution).

Section 4 gathers the results of the survey for step 2 (factsheet of the specific requirements that would favor or hinder the uptake of each solution.).

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3. Barriers and obstacles for transferability

3.1. Short presentation of the solutions

DWC is developing and bringing to the market a panel of 15 digital solutions. Figure 1 presents the solutions, their role on the water cycle and the type of digital solutions at stake. Details on each digital solution can be found on the website digital-water.city.

Figure 1: Panel of digital solutions developed within DWC

The digital solutions and their assessment are presented in a series of deliverables. For more information, the reader is invited to refer to the following reports.

Deliverable	Link with this report
D11 Practical manual on innovative sensor integration, validation and operation and maintenance in existing water infrastructure	The report provides technical information and an assessment of DS1
D12 Early warning and improved decision support for health protection in water reuse and bathing water	The report provides technical information and an assessment of DS2 and 3

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D22 Performance and ROI of urban water systems: benefits obtained through the deployment of digital solutions	The report provides demonstration outcomes and a performance assessment of DS5.1, 5.2, 7, 8, 9, 11, 12, 13, 14, 15
D24 Technical documentation of the digital solutions and key requirement for successful deployment	The report provides technical description of DS5.1, 5.2, 7, 8, 9, 11, 12, 13, 14, 15
D51 Plan for exploitation of DWC results	The report presents the results of the 2 transferability workshops; in particular, Appendix C gives specific insights and recommendations for the development of the digital solutions.

3.2. Drivers and obstacles by solution

Sensors for real-time in-situ E.coli and enterococci measurements	1
Main developer: FLUIDION Main contact: Dan Angelescu (FLUIDION)	
Quick description	
The ALERT System is a new sensor for real-time bacterial measurements, manufactured by the company Fluidion. The device is fully autonomous, remotely controllable, installed in-situ and allows rapid quantification of E.coli or enterococci concentrations. Suitable for monitoring water and the environment, it performs seven measurements on a battery charge. Installed in-situ, it allows rapid quantification of bacterial concentration and emits real-time automatic alerts.	
What are the main drivers of implementation? What are the factors that could accelerate and boost the uptake of the solution?	
Validated performance through side-by-side testing and real implementations by trusted utilities and regulatory agencies. **Simplicity of usage**, and the full automation provided. **Change in EU regulations** to accept digital solution for bathing water monitoring, in addition to or in lieu of existing lab-based methods, could accelerate adoption. **Unified regulations**, and a unified validation body for new solutions, would provide a framework for adopting such solutions at larger scales.	
What are the main obstacles and barriers for implementation? What are the factors that could limit the uptake of the solution?	
While there are general EU regulatory frameworks, they are implemented differently and local regulations depend on each country. There are **no general European standards** on approved methods for bathing water monitoring. The solution would benefit from being combined with a faster proxy for rapidly identifying the arrival of a pollution wave.	

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Machine-learning based Early Warning System for bathing water quality	2
Main developer: KWB Main contact: Wolfgang Seis (KWB)	
Quick description	
SWIM:AI is an early warning system that provides real-time assessment of bathing water quality as an open source solution. Based on machine learning as well as statistical modeling, SWIM:AI predicts the bacteria concentration in specific river sections. SWIM:AI processes a range of local data such as precipitation, flow, or temperature.	
What are the main drivers of implementation? What are the factors that could accelerate and boost the uptake of the solution?	
SWIM:AI builds on the idea that digital solution can empower bathing water quality management by using available environmental data to better inform stakeholders and citizens about contamination risks. Main driver for uptake is the need to **document the hygienic quality of bathing waters** on a daily basis. Health authorities can thus warn of pollution and health risks in due time and avoid the risks of exposing bathers to pollution events. SWIM:AI provides daily complete predictions of water quality at bathing sites independent of the 4-weekly microbiological analyses required by law and generates reliable data to support authorities in managing bathing permits in urban bathing areas. Further drivers for uptake are • **Prevent systematic closure of bathing sites** after each heavy rain event: the tool allows to optimize opening and closing of bathing sites based on available data and model predictions • **The need to improve communication** of bathing water quality to the population • The possibility to **increase the tourist attractiveness** of bathing sites through the active promotion of water quality on municipal websites and in tourist portals • The **interoperability of the system** with FIWARE might facilitate the future implementation of the solution in cities familiar with the reference architecture. Last but not least, SWIM:AI supports the **requirements of the European Bathing Water Directive** and offers a proactive implementation of upcoming tightening of EU directives on bathing water quality monitoring, according to which microbiological monitoring must be supplemented by early warning systems.	
What are the main obstacles and barriers for implementation? What are the factors that could limit the uptake of the solution?	
Lack of informative data: for making correct predictions a ML models needs informative data on different states of the systems. If such a rich dataset is missing model prediction might be off. **Additional cost and competences**: While the software is free, its implementation will require some competences for running and maintaining it. **Limited legislative support**: Bathing water quality managers are well aware that results obtained by manual grab sampling and laboratory analysis are too slow for an efficient and safe day-to-day bathing water quality management. Nevertheless, the current European Bathing Water directive does not directly support the use of prediction modeling and real-time analytical approaches for	

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decision making, e.g. the check samples for re-opening after a short-term pollution is not a suitable instrument for supporting such decisions.

Early Warning System for safe water reuse	3

Main developer: UNIVPM

Main contact: Francesco Fatone (UNIVPM)

Quick description

The early warning system (EWS) for safe water reuse is a risk-based management tool for sanitation systems. It aims to prevent bacterial and toxic contamination linked to the reuse of treated wastewater for agricultural irrigation based on:

- A comprehensive network of multi-parameter sensors at the wastewater treatment plant (WWTP)
- New sensors for real-time in-situ measurement (e.g. for E.coli measurement DS1)
- Machine learning / statistical correlation to assess contamination risk

It contributes to the implementation of the risk-based Sanitation Safety Plan based on the WHO approach.

What are the main drivers of implementation? What are the factors that could accelerate and boost the uptake of the solution?

The main driver for implementing EWS lies on its capacity to **support decisions and actions for water reuse risk management** and minimization using a combination of routine lab and real-time data coming from the conventional and/or innovative sensors installed in a WWTP, which often require further processing/analytics and thus are currently not reliable or unexploited.

Moreover, the EWS can be integrated in a digital twin and used to support single section or plant-wide **process control and optimization**, since it interconnects the information coming from different sectors of the WWTP.

The EWS uptake could be boosted is **water reuse risk management plans** would include possible use of validated soft sensors based on existing data available in WWTPs.

What are the main obstacles and barriers for implementation? What are the factors that could limit the uptake of the solution?

The main obstacles for the implementation of the EWS lie on the **reliability and qualitative variability of the real-time data** to be used as inputs of the EWS.

Data quality is not commonly monitored by water utilities, which can lead to major efforts (data cleaning, outlier detection, etc.) to build the data model required to feed the EWS.

The **low digitalization** level of some (small) WWTPs with few sensors and/or scarce sensors/meters maintenance could hinder the applicability of the EWS.

Finally, the **low trust on the outcomes of digital tools** and lack of **standardization** can make the results not usable or acceptable by environmental and/or health authorities.

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WebGIS platform for improved decision making in water reuse	4
Main developer: CAP Main contact: Marco Bernardi (CAP)	
Quick description	
The WebGIS Acque di Lombardia is a web-based information system which gathers data related to sewer networks, drinking water networks and land use. Georeferenced data are available online and from mobile devices on a single platform. The system is updated in real time and accessible to all users for consulting and managing the data.	
What are the main drivers of implementation? What are the factors that could accelerate and boost the uptake of the solution?	
Drivers of the solution are related to the **potential to reuse the treated wastewater** from WWTP and thus to the obtained water quality and local infrastructure. WebGIS supports the **management of the system**, being potentially able to describe real-time characteristics and quality classes of the water and the associated risk for human health. This digital solution is replicable in other cities, implementing **new site-specific platforms**.	
What are the main obstacles and barriers for implementation? What are the factors that could limit the uptake of the solution?	
The main obstacle for the implementation of the solution is related to the **data availability**, needed for the development of the tool, e.g. base map, identification of agricultural areas and municipalities. Another issue is related to the **specific IT infrastructure** required for the development of the system.	
Active unmanned aerial vehicle for analysis of irrigation efficiency	5.1
Main developer: UNIMI/UNIVPM Main contacts: Gian Battista Bischetti (UNIMI), Adriano Mancini (UNIVPM)	
Quick description	
The solution is an innovative combination of an unmanned aerial vehicle (UAV or drone) and multi-spectral imagery for remote detection of water stress. It improves the real-time knowledge on water stress in the soil-plant-atmosphere system and enables analysis of the efficiency of irrigation schemes.	
What are the main drivers of implementation? What are the factors that could accelerate and boost the uptake of the solution?	
In many areas across the world, freshwater resources are becoming more and more scarce due to climate change and direct human activities (like unsustainable water uses), for example in the Mediterranean region. The main driver for uptake is the urgent **need for improved monitoring**, understanding and management of irrigation practices.	

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Another key driver is the **increased awareness of farmers about the underlying opportunities** offered by precision farming and monitoring solutions (e.g. the perspective to save investment and costs on irrigation water and to improve yields).	
What are the main obstacles and barriers for implementation? What are the factors that could limit the uptake of the solution?	
One of the main obstacles is represented by the **complexity and cost of the technologies**. Nonetheless, technology costs will reduce in the coming years, considering that every year the number of users and installations (e.g. IoT agronomic sensors) is growing. Funds that support farmers and agronomists investing in new technologies are available from national and EU grants. Another potential obstacle is represented by the **required level of digitalization** of end-users (i.e. farmers). However, farmers could be supported in this either through interaction with local/national farmer associations or by companies that provide the services to integrate data into the proposed architecture. Moreover, financial support for farmers to digitalize their farms could be an extra help. In some areas located in the proximity of cities or critical infrastructure, **restrictions to flights** might be in place to preserve the airspace.	
Match making tool between water demand for irrigation and safe water availability	5.2
Main developer: UNIMI/UNIVPM Main contacts: Gian Battista Bischetti (UNIMI), Adriano Mancini (UNIVPM)	
Quick description	
This match making tool MMT is a web-based application to manage demand for treated wastewater for agricultural irrigation. It is based on the assessment of irrigation needs using remotely sensed data (DS 5.1) as well as on the amount and quality of available reused water (DS 3). The platform will be used as a communication tool to inform farmers about the possible water supply and to inform wastewater treatment plant (WWTP) managers about the current irrigation needs (both in terms of quantity and quality).	
What are the main drivers of implementation? What are the factors that could accelerate and boost the uptake of the solution?	
In many areas across the world, freshwater resources are becoming more and more scarce due to climate change and direct human activities (like unsustainable water uses), for example in the Mediterranean region. This **urgently calls for alternative water supplies** such as treated wastewater and represents a driving factor for implementation of the MMT, that would facilitate treated wastewater reuse in agriculture. As climate change accelerates and water demands increase, European, national, or regional regulations are increasingly being adapted for addressing these challenges, including those that concern the use of treated wastewater in agriculture. The widespread availability of more detailed and standardized rules on this matter (e.g. **monitoring standards to verify compliance** with minimum requirements for reuse, restrictions, etc.) is another factor that could accelerate the uptake of this solution. Finally, another factor would be an **increased awareness, on the farmers' side**, about the opportunities underlying the water reuse practice through the MMT (e.g. the perspective to save	

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money on water/fertilizer and to improve yields, or even to shift to more profitable crops), and, on the utilities' side, about the opportunities to save energy and reduce CO2 emissions or even to sell the treated wastewater to farmers by using the tool.	
What are the main obstacles and barriers for implementation? What are the factors that could limit the uptake of the solution?	
One potential obstacle would be the **psychological barrier** (e.g. health risk perception, trust in the utility) of consuming food that has been irrigated with treated wastewater, as this would limit the **acceptance of the water reuse practice** in agriculture as a whole. Although aim of the emerging regulations is to make sure the practice is always carried out safely, with a sufficiently high and fit-for-purpose water quality and no connected health risks. **The need to invest in new infrastructure** could be another obstacle, although EU policies at multiple levels (from regional to national) are already allocating funds for converting current systems into new pressurized distribution networks. Finally, a barrier could be linked to the fact that farmers, other than investing in crop/water level sensors for monitoring crop status and irrigation needs, need to start interacting with the tool in their practice (e.g. providing info on their crops, irrigation techniques, etc.). Although the **digitalization level needed** for this will be minimum and the user-friendly interfaces will help address this obstacle.	
Serious game for the water reuse – carbon – energy – food – climatic nexus	6
Main developer: UNIVPM Main contacts: Francesco Fatone, Adriano Mancini (UNIVPM)	
Quick description	
Based on scientifically sound and validated wastewater treatment and crop growth models, the solution is a web-based serious game for near real-time audit of water reuse – carbon – energy – food – climatic nexus. The game aims at engaging the widest public as possible to raise awareness and overcome social and economic barriers to water reuse. The game-embedded visualization tool will allow citizens to interact with data and support the understanding of the complexity of the nexus of water availability, carbon emission, energy consumption, food crop productivity. It aims at communicating the benefits of water reuse in terms of impacts on each aspect of the nexus.	
What are the main drivers of implementation? What are the factors that could accelerate and boost the uptake of the solution?	
The main drivers for the implementation of the serious game are related to the **raise of social and public awareness** about systemic and complex challenges (nexus) addressed by water reuse practice. The inclusion of **public awareness in corporate and regional sustainability reporting** might boost the uptake of the solutions.	
What are the main obstacles and barriers for implementation? What are the factors that could limit the uptake of the solution?	

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The main obstacle on the implementation of the solution is the **need of reliable and representative data** required to make regional scenarios and provide likely results, according to the site-specific conditions of a territory. There is still a **low interest in science-based public awareness** which is considered hard and ineffective to raise and communicate, even by serious gamification.	
Mobile application for data collection of drinking water wells	7.1
Main developer: VRAGMENTS Main contacts: Alex Sperlich (BWB), Stephan Gensch (VRAGMENTS)	
Quick description	
This solution (Well Diary) comprises a software application for mobile devices that facilitates efficient data provision and collection in the field for drinking water well operation and maintenance. The application enables interoperability of data across various departments within utilities and across additional stakeholders, and eases data processing routines and visualisation of well condition characteristics.	
What are the main drivers of implementation? What are the factors that could accelerate and boost the uptake of the solution?	
A potential driver is that the Well Diary **can be extended and modified** efficiently to cater to other assets in the field (e.g. pipes, pumps, etc.), due to its **standardisation potential** (e.g. using BIM/IFC as an internal model). As such, partners have expressed interest in the proposed solution.	
What are the main obstacles and barriers for implementation? What are the factors that could limit the uptake of the solution?	
A potential obstacle for the transfer is the **applicability of the solution to the infrastructure at hand**. If local drinking water production does not rely on water wells, DS7.1 cannot be directly applied. Potential barriers are **connectivity to field operators**, **user acceptance** and the **integration into a secure productive environment**. Also, the **availability of mobile devices** is a prerequisite for the use of DS7.1. Apart from that no further site requirements have to be fulfilled.	
Forecasting tool for strategic planning and maintenance	7.2
Main developer: KWB Main contacts: Hella Schwarzmüller, Michael Rustler (KWB)	
Quick description	
The solution is a machine-learning based prediction tool which supports utilities in shifting from time-based maintenance of single wells to condition-based maintenance with a view to all available wells and the target capacities of the utility.	
What are the main drivers of implementation? What are the factors that could accelerate and boost the uptake of the solution?	
Drivers for transfer and replication can be the **increasing usage of (i) sensors** delivering continuous measurement of key parameters such as water level and flow, (ii) **database storage solutions** for	

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well data and (iii) **increasing experience with semi-automated data processing** and machine-learning approaches in other fields of water infrastructure management as data science has been gaining momentum in recent years. These technologies are for example already applied for failure prediction of drinking water (and sewer) pipe networks, where in a similar approach factors for fast or slow ageing and certain constructive and operational parameters are set into relation to identify and prioritize maintenance needs. The fact that **wells need regular preventive or reactive maintenance** in order to keep their capacity and constructive integrity is widely acknowledged nowadays and data-driven prioritization of needs will thus help to schedule limited human and financial reports for the highest return on investment.	
What are the main obstacles and barriers for implementation? What are the factors that could limit the uptake of the solution?	
The solution will be applicable for and transferable to utilities producing drinking water from vertical filter wells. However, to apply the solution, **basic well data** need to be available over a certain period of time in order to be able to train the machine-learning algorithms. Data should comprise constructive properties (filter length, material, position of intake area etc), basic hydrochemical characteristics of the raw water (pH, redox potential, electric conductivity, oxygen and iron concentration and others) and water level and flow data. Potential obstacles are thus a **lack of data, data gaps or a too short history of well data**.	
DTS sensor for tracking illicit sewer connections	8
Main developer: P4UW Main contact: Remy Schilperoort (P4UW)	
Quick description	
Distributed temperature sensing (DTS) is a technique used to detect and locate illegal connections and extraneous inflows in sewer systems. It does this by using fiber-optic cables as very large temperature sensors.	
What are the main drivers of implementation? What are the factors that could accelerate and boost the uptake of the solution?	
An important driver for the use of DTS are problems with the hygienic reliability of surface water, for instance when this is used as bathing water, or as source for the production of drinking water. In these cases, there is a **strong urge to pinpoint and remove the source(s) of the bacterial contamination** of the water. Another potential driver is the **growing interest in surface water quality** and biodiversity in European, national, and regional politics, even though the European Water Framework Directive primarily focuses on large scale water bodies, and less on smaller urban surface water bodies. Important here is the local context and appreciation of surface water quality. Potential drivers for the application of DTS in other cities will be **successful demonstrations of the solution in different settings**, dissemination of the acquired knowledge in pilots and cost reduction through innovations (e.g. fibre-optic cable connectors) and larger scale applications.	

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What are the main obstacles and barriers for implementation? What are the factors that could limit the uptake of the solution?	
Cost is probably the main potential obstacle for the transfer and replications of the DTS solution on a large scale to other cities (costs for DTS unit, fiber-optic cables, data analysis). The **willingness to invest** in such equipment requires a strong and long-term drive to solve problems associated with illicit connections in an area. In cities where illicit connections represent a significant contribution to environmental impact or an impediment to water uses such as swimming, the solution becomes much more cost effective, in view of the massive investments required to upgrade the network. In general, there are no specific site barriers to consider for the solution. The application in storm sewers (searching for wastewater inflows) is rather straightforward, but application in foul sewers (searching for infiltration and inflows that overload the system) requires a stringent focus on the (prevention of) clogging of the sewer as a result of the build-up of pollution around the fibre-optic cables. A minor potential obstacle is the **availability of data**. Since DTS measurements can only be usefully interpreted if the sewer system layout is sufficiently known, it is not recommended to apply DTS if the sewer object database is not reliable or lacks entirely. For most urban environments, however, geodata of sufficient quantity and quality is available in the municipal sewer data administration.	
Sensors and smart analytics for tracking illicit sewer connections hotspots	9
Main developer: KANDO Main contacts: Ricardo Gilead Baibich, Gali Fux (KANDO)	
Quick description	
The robust KANDO Smart Unit is an innovative solution used to track industrial discharges and illicit connections in sewer networks by leveraging Internet of Things (IoT) technology and data analytics. It combines several flexible units for real-time water quality monitoring with multi-parameter sensors and automatic sampling. The solution enables reduction of pollution impacts by continuously detecting sources of pollution across the city. It can pin-point the location of illicit connections and automatically identify pollution events using distributed predictive analytics, cloud transmission and visualisation.	
What are the main drivers of implementation? What are the factors that could accelerate and boost the uptake of the solution?	
The main driving force for the implementation of the solution is the poor water quality still found in many urban lakes and rivers and the increasing willingness to use water bodies for swimming or recreation. **Stricter regulation of water quality standards** (often measured in coliforms/ml) to protect public health require proper maintenance of drainage systems and elimination of illicit sewer connections. The easy operational manageability and the **low expenditure** is an advantage of this solution. The solution is easy and safe to install, commission and move between different location, so the network size is not a barrier. Compared to traditional solutions (CCTV) the solution's success rate, as well as value for money spent is much higher. Another driver for implementation is the **network design**. In cities where the stormwater drainage system is above the sewer system, it is likely to expect illicit sewer connections. Preventing these	

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incidences from the beginning would require greater efforts, therefore it's hard to find a permanent solution to the problem.	
What are the main obstacles and barriers for implementation? What are the factors that could limit the uptake of the solution?	
The application of the demonstrated solution is primarily designed for use in storm water sewer networks. The **existence of a separate sewer system** is therefore a prerequisite. Apart from that, no further site requirements. The sensors are submerged in water, therefore breaks between flows require more **frequent maintenance of the hardware**. Kando is trying to eliminate this barrier by developing a "touch-less" sensor, which will not be submerged in water and could operate for longer period of times, lowering labour costs. A **conceptual and regulatory barrier** to the implementation of the solution is the approach to wastewater as "waste", detaching it from the water cycle. Very few quality standards for wastewater quality exist, and fines for discharge of non-compliance wastewater have little effect.	
Augmented Reality (AR) mobile application for groundwater visualization	10
Main developer: VRAGMENTS, KWB Main contacts: Stephan Gensch (VRAGMENTS), Christoph Sprenger (KWB), Alex Sperlich (BWB)	
Quick description	
This augmented reality (AR) mobile application integrates a 3D geological model of the Berlin area with groundwater flow and quality simulations to immerse the user into the geological subsurface. It relies on the potential of AR to inform the public about the role and challenges of groundwater in an engaging and informative way. The application may be used anywhere in a table-top mode to access a holistic view of the Berlin area and individual sites of interest (e.g. specific drinking water wells, lithological structures), or location-based with site-specific information on aquifers and groundwater flow.	
What are the main drivers of implementation? What are the factors that could accelerate and boost the uptake of the solution?	
The predominant driver for the implementation of DS10 is the **need to increase awareness** of a broad public audience in Berlin to protect its drinking water resource. While this can (and has been done) in various ways using traditional media, **audiences shift to modern means of information** and education provision. Augmented Reality has enormous potential to bring complex messages across and since groundwater processes are three-dimensional and over time, a comparable visualization using 3D animated models in AR Important factors for an uptake are both on end user and producer side. For end-users, the app must • adequately inform them on the topics with correct and accessible information, • be easy to use, and	

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• provide satisfaction beyond the efficacy of the messages to users, e.g., by the app being enjoyable and fun to use, or by helping people being considered knowledgeable among their peer group. For producers, the establishment of a content production chain is key. Specific geological or hydrological layers must be digitally available and MODFLOW 2005 simulations must be prepared for specific scenarios and later ingested and integrated into the scenarios.	
What are the main obstacles and barriers for implementation? What are the factors that could limit the uptake of the solution?	
While AR applications are increasingly available on modern smartphones, **general uptake is limited to people owning AR capable devices**. This current shortcoming can be expected to be decreased in the future, as AR capabilities become increasingly available due to technical advance and further innovation that create news business cases drives widespread adoption. A second limitation is the **current bottleneck in manual processes to generate groundwater flow visualizations**. The data source is using MODFLOW 2005 and additional scripts to prepare the data for app ingestion. This work is done by KWB and needs to be prepared for every scenario to be displayed. The refined data is ingested by VRAG using a developed Unity tool and then added manually to a scenario.	
Sewer flow forecast toolbox	11
Main developer. DHI Main contact: Sten Lindberg (DHI)	
Quick description	
The sewer flow forecast toolbox is a machine-learning (ML) based tool for forecasting flow in the sewer network and inflow to the wastewater treatment plant (WWTP), with forecast lead time of up to 48 hours. The tool is based on a combination of (1) real-time water level and flow sensor data from the sewer system, (2) rain gauge data, (3) weather radar observations and nowcasts, and (4) weather forecasts from numerical weather prediction models. The solution provides accurate flow modelling forecast and horizon to support the integrated management of the sewer network and WWTP.	
What are the main drivers of implementation? What are the factors that could accelerate and boost the uptake of the solution?	
With a more accurate and reliable inflow forecast, the operation of the treatment plant may be optimized, e.g. by changing from dry weather operation to wet weather when the flow is expected to exceed certain flow limits. This will **reduce the discharge of contaminants and energy consumption**. Machine Learning is an attractive methodology, fast to train and which does not necessarily require large amounts of data. The solution may be a **cost-effective way of meeting increased demands for better treatment or reduced energy use**.	
What are the main obstacles and barriers for implementation? What are the factors that could limit the uptake of the solution?	

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A fundamental requirement for producing the inflow forecasts, is **reliable rainfall forecast data**, whether from radar or weather prediction models. The concentration time (time from the rain hits the surface till it reaches the WWTP) is typically quite limited (few hours), which underlines the need for forecasted rainfall values. DS11 will primarily be relevant for combined sewer catchments, or for separate sewer systems with high rates of rainfall dependent inflow/infiltration. Apart from that, there are no further site requirements. The immediate attraction for a utility to implement an inflow forecast tool, may be challenges by **organisational aspects** in some cases, where the operations of the sewer network and the WWTP are managed in different departments depending on the individual goals.	
Interoperable DSS and real-time control algorithms for stormwater management	12
Main developer. DHI Main contact: Sten Lindberg (DHI)	
Quick description	
This Decision Support System (DSS) is an innovative tool for the sustainable operation of the integrated sewer network and wastewater treatment plant (WWTP). It is based on a series of level and flow sensors within the sewer network, WWTP operation data and accurate flow forecast at the inflow of the WWTP (solution 11).	
What are the main drivers of implementation? What are the factors that could accelerate and boost the uptake of the solution?	
Goal of the DSS is to optimise treatment capacities, pumping strategies and in-sewer flow allocation to make the best use of existing infrastructure for stormwater handling. It can support utilities in planning measures for **flow attenuation and reduction of combined sewer overflows** to the receiving waters. The DSS can also **enable operational staff** to understand the added value and risks of different integrated control strategies between sewer network and WWTP. Finally, it contributes to the creation of an **overview of the entire system** and to the improved understanding of its functionality.	
What are the main obstacles and barriers for implementation? What are the factors that could limit the uptake of the solution?	
The DSS requires the **availability of a calibrated sewer hydraulic model**. On the infrastructure side, it is especially relevant when **storage volume can be activated** in the network. Finally, it requires the **availability of operational devices** (gates/pumps) within the network to implement the necessary control actions.	

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Web platform for integrated sewer and WWTP control	13
Main developer. DHI Main contact: Sten Lindberg (DHI)	
Quick description	
The web-based tool SAMDUS is an interoperable visualisation platform that provides data and analytics to all stakeholders responsible for the integrated management of sewer networks and wastewater treatment plants (WWTPs) in an urban area. The platform enables the sharing and visualisation of data from a series of sensors, models, and decision support systems. It integrates the total system dynamics and facilitates real-time decision-making across all utilities and entities, increasing preparedness for high-flow events.	
What are the main drivers of implementation? What are the factors that could accelerate and boost the uptake of the solution?	
A key driver for the uptake of the solution is the **need for easy access to information and overview** for operational staff **across a large number of utilities and organizations**. The solution is also particularly relevant to ease communication between the utility and regulating authority and the public. Finally, the solutions can support **safe and sustainable storage** of data and information for possible later use.	
What are the main obstacles and barriers for implementation? What are the factors that could limit the uptake of the solution?	
The solution is relevant for utilities with a **certain level of digitalization**. Lack of sensors and data, makes it less relevant to collect and present information. Another obstacle is that the selected tools for modelling and web may be in conflict with **corporate policies** (issue of interoperability).	
Low-cost temperature sensors for real-time CSO and flooding monitoring	14
Main developer: ICRA, IOTSENS Main contact: Oriol Gutierrez (ICRA), Neus Amela (IOTSENS)	
Quick description	
This solution is based on deployment of a network of innovative low-cost temperature sensors to estimate emissions from combined sewer overflows (CSO) across a large number of points in a sewer system. The sensors are installed at the overflow crest and measure air temperature during dry-weather conditions and water temperature when the overflow crest is submerged in case of a discharge. A CSO event and its duration can be detected by a shift in temperature, thanks to the temperature difference between air phase and stormwater discharge.	
What are the main drivers of implementation? What are the factors that could accelerate and boost the uptake of the solution?	
With regards to the drivers for replication, DS14 is very **simple, cost-effective, and robust** thus it is easy to replicate in a wide range of cities. CSO is a worldwide problem and there is a **need to monitor**	

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CSOs both for environmental and legal reasons. In fact, within DWC the replication is already happening as Gruppo CAP from Milano is adopting DS14 solution in one of their sewer catchments. In general, the solution can be of great support for any city with a combined sewer system with no further site requirements, given access to the overflow structures for sensor installation.	
What are the main obstacles and barriers for implementation? What are the factors that could limit the uptake of the solution?	
About replication obstacles, some cities/water utilities already have CSOs monitoring systems deployed. Those might be **reluctant to change** to DS14 while it does not outperform their current tools. Also, the current version of DS14 only provides information on the occurrence and duration of CSOs. Although this information is very relevant and complies with current regulations, some **local/national policies could be stricter** and ask also for volume and quality quantification. We are working to incorporate these features in DS14. Another concern for water utilities is related to the **installation and maintenance** of the sensors as sewers are a harsh environment. Installation might indeed require an effort from the sewer field teams but once installed, the solution is designed to work steadily under sewer aggressive conditions, minimizing the maintenance and time of underground access. Finally, a common obstacle is the **lack of budgets** allocated for sewer monitoring, which is still the case in a considerable number of cities.	
Smart sewer cleaning system with HD camera and wireless communication	15
Main developer: IPEK Main contact: Martin Stümpfle (IPEK)	
Quick description	
The Xpection solution is a smart combination of a high-definition (HD) camera, a sewer-cleaning nozzle and wireless communication technology. It improves interoperability between cleaning and inspection teams and boosts the performance of sewer cleaning processes by saving time, fuel and water compared to conventional cleaning processes.	
What are the main drivers of implementation? What are the factors that could accelerate and boost the uptake of the solution?	
The solution can be deployed in any sewer network and applied to pipes with diameters from 200 to 1000 mm, given that the utility disposes of trucks for sewer cleaning. Apart from that, there are no further site requirements.	
What are the main obstacles and barriers for implementation? What are the factors that could limit the uptake of the solution?	
As with any new technique, end-users will have to adapt to the new technique. However, it is designed to be used without long special trainings. Especially in cities with large and flat sewer systems which are often subject to sedimentation and blockages, the benefits in saving water and energy can be very high.	

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4. Factsheet requirements for uptake of the solutions

4.1. DS1. ALERT sensors for real-time in situ E.coli and enterococci measurements

Topics	Sub-topic	Explanation	Specific drivers and obstacles
Environmental	Precipitation pattern / rainfall	*Could the type of precipitation (intensity, frequency) influence the use of the solution?*	Yes. Variable precipitation patterns and intense rain can generate unpredictable short-term pollution which may affects small areas or complete river basins. These require active monitoring using a sensor such as ALERT V2 and are difficult to anticipate or model, especially in cities with complex sewage systems.
	Climate condition and climate change	*Does local climate settings influence the successful implementation of the solution?*	Absolutely, climate change leads to less predictable rain patterns, and to more extreme precipitation events and storms. The "first flush" pollution brought by a rain event after long draught requires high-frequency active monitoring, easy installation, and ALERT V2 provides a very elegant solution.
	Topography	*Is the topography of the city relevant for the solution?*	Not really
Technical	Type of network and infrastructure	*Is the solution adapted to only specific types of networks (e.g. combined sewer)? How universal is it?*	The ALERT V2 operates equally well regardless of the network type, and it can monitor both dry weather pollution (including that caused by WWTP and illegal sewage connections to rainwater network in separate system) and wet weather pollutions from CSO in combined sewer systems.
	Required investment, infrastructure, and material	*Does the city need to have or purchase specific assets or material to use the solution?*	The city needs to purchase ALERT V2 instruments or service contracts that include installation of the instruments.
	Asset condition	*Is the structural and operational condition of the local assets relevant?*	Yes, the ALERT V2 needs to be in good operational condition, and the reagent cartridges need to be within their useful lifetime

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IT	Interoperability requirements	*Does the city need specific IT infrastructure ?*	No, the ALERT V2 operates on existing cellular networks.
	Level of digitalization	*Is a certain level of digitalization required to use the solution?*	The solution is fully digital, data is provided through a cloud visualization and analytics interface or using a secure API for integration in third-party dashboards.
	Level of standardization	*Are there any standards required?*	N/A
	Cybersecurity	*Are there any cybersecurity requirements?*	The cloud interface as well as the communication with the devices is secured through SSL certificates.
Legal	Local, national of EU policy	*Does the solution support the compliance with given policies?*	Change in EU regulations to accept digital solution for bathing water monitoring, in addition to or in lieu of existing lab-based methods, could accelerate adoption
Governance and social	Social acceptability	*What could influence the acceptance of the solution by the utility and/or the citizens?*	The fact that it is a fully objective solution that can provide automatic early warning in case of pollution makes the ALERT V2 a valuable asset for citizens and utilities. The ALERT technology can also be used to generate citizen science.
	Teamwork and responsibility	*Does the solution requires specific team organizations?*	Not really. It does require a technician for maintenance, and a decision maker for deciding how to use the data.
	Required skills	*Does the solution requires specific skills?*	No, it is simple to use by minimally trained individuals. An understanding of microbiology and local regulations is important for the manager in charge of implementing this solution.
Further	/	*Further requirement?*	

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4.2. DS2. Machine-learning based Early Warning System for bathing water quality

Topics	Sub-topic	Explanation	Specific drivers and obstacles
Environmental	Precipitation pattern / rainfall	*Could the type of precipitation (intensity, frequency) influence the use of the solution?*	Yes, ML learning-based models depend on the availability of informative paired data. The proposed solution predicts short-term pollution episodes at bathing waters, which are often negatively influenced by rainfall. The latter may have divers characteristics, for which informative data is needed.
	Climate condition and climate change	*Does local climate settings influence the successful implementation of the solution?*	Not directly
	Topography	*Is the topography of the city relevant for the solution?*	Not directly
Technical	Type of network and infrastructure	*Is the solution adapted to only specific types of networks (e.g. combined sewer)? How universal is it?*	Universal
	Required investment, infrastructure, and material	*Does the city need to have or purchase specific assets or material to use the solution?*	The city has to collect informative data on fecal indicator bacteria.
	Asset condition	*Is the structural and operational condition of the local assets relevant?*	Not directly
IT	Interoperability requirements	*Does the city need specific IT infrastructure ?*	The city needs very standard IT infrastructure which will not exceed basic needs. The solution is FIWARE compatible.

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	Level of digitalization	*Is a certain level of digitalization required to use the solution?*	To generate real time predictions the environmental data of the predictor variables (rainfall, river flow, etc.) have to be transferred in real time.
	Level of standardization	*Are there any standards required?*	Our solution offers to use the FIWARE standard for Water, WaterQuality, and Weather.
	Cybersecurity	*Are there any cybersecurity requirements?*	The solution can run on a separate server without connection to any sensitive system.
Legal	Local, national of EU policy	*Does the solution support the compliance with given policies?*	Yes, with the fulfillment of the bathing water directive
Governance and social	Social acceptability	*What could influence the acceptance of the solution by the utility and/or the citizens?*	The quality of the predictions can influence the acceptance of the solution. Utilities and the public have to trust the predictions.
	Teamwork and responsibility	*Does the solution require specific team organizations?*	The implementation of the solution requires the cooperation of different utilities and decision makers. It does not need a specific team organization.
	Required skills	*Does the solution require specific skills?*	A high-level understanding of bathing water quality management and interpretation of model results is needed for correctly interpreting model outputs.
Further	/	*Further requirement?*	/

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4.3. DS3. Early Warning System for safe reuse of treated wastewater for agricultural irrigation

Topics	Sub-topic	Explanation	Specific drivers and obstacles
Environmental	Precipitation pattern / rainfall	*Could the type of precipitation (intensity, frequency) influence the use of the solution?*	The EWS should be developed using the widest set of data available, including extreme events, in order to be trained/validated and to provide affordable results in different conditions.
	Climate condition and climate change	*Does local climate settings influence the successful implementation of the solution?*	If climate settings do not show extreme and sudden changes, the solution is adaptable to local conditions after customization/calibration
	Topography	*Is the topography of the city relevant for the solution?*	Topography may influence catchment and sewer network, but once the EWS is calibrated/validated with local data, its outputs include the local conditions.
Technical	Type of network and infrastructure	*Is the solution adapted to only specific types of networks (e.g. combined sewer)? How universal is it?*	The EWS is adapted to WWTPs or reclaimed water facilities. It will need to be customized depending on the local treatment processes
	Required investment, infrastructure, and material	*Does the city need to have or purchase specific assets or material to use the solution?*	A network of sensors and connection to data management platform is required, but this is quite a standard in existing WWTPs
	Asset condition	*Is the structural and operational condition of the local assets relevant?*	The structural and operational conditions of the WWTP is relevant for the development of the EWS
IT	Interoperability requirements	*Does the city need specific IT infrastructure?*	The WWTP or the reclamation facility require a network of sensors and remote control, but in most cases, they are already implemented
	Level of digitalization	*Is a certain level of digitalization required to use the solution?*	The digitalization level required is fitting the data management systems usually reached by water utilities

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	Level of standardization	*Are there any standards required?*	The EWS will support risk management/minimization for operators actions and decision support. However, the digital solutions will not replace lab standard analysis. The inclusion of digital solutions in the forthcoming EU water reuse risk management planning guidelines would boost the application of the solution
	Cybersecurity	*Are there any cybersecurity requirements?*	The standard cybersecurity requirements already available in WWTPs and water utility assets are sufficient
Legal	Local, national of EU policy	*Does the solution support the compliance with given policies?*	The EWS support compliance with the development of risk management plans for water reuse
Governance and social	Social acceptability	*What could influence the acceptance of the solution by the utility and/or the citizens?*	The EWS will be accepted by water utilities if the results are reliable and costs of traditional monitoring can be saved, the society will need to be informed about the added value of the digital solutions which is complementing (not replacing) the standard lab analysis
	Teamwork and responsibility	*Does the solution require specific team organizations?*	The EWS requires proper maintenance plan of sensors and meters by the water utility operators to guarantee sufficient reliability of source/raw data
	Required skills	*Does the solution require specific skills?*	The EWS needs to be periodically validated and calibrated by skilled personnel. Process engineers and data scientists should collaborate in team
Further	/	*Further requirement?*	/

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4.4. DS4. WebGIS platform for improved decision making in water reuse

Topics	Sub-topic	Explanation	Specific drivers and obstacles
Environmental	Precipitation pattern / rainfall	*Could the type of precipitation (intensity, frequency) influence the use of the solution?*	No, it is not relevant
	Climate condition and climate change	*Does local climate settings influence the successful implementation of the solution?*	No, it is not relevant
	Topography	*Is the topography of the city relevant for the solution?*	No, it is not relevant in the platform itself. It is important in the definition of the areas potentially served by the reclaimed water from each WWTP.
Technical	Type of network and infrastructure	*Is the solution adapted to only specific types of networks (e.g. combined sewer)? How universal is it?*	The solution is site-specific, so it is adapted to describe all the situations in which water reuse is possible according to EU regulation 2020/741.
	Required investment, infrastructure, and material	*Does the city need to have or purchase specific assets or material to use the solution?*	The solution itself does not need any assets
	Asset condition	*Is the structural and operational condition of the local assets relevant?*	The solution itself does not need any assets
IT	Interoperability requirements	*Does the city need specific IT infrastructure?*	Specific software for the GIS implementation is required
	Level of digitalization	*Is a certain level of digitalization required to use the solution?*	WebGis platform is intended for the digitization of the utility database

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	Level of standardization	*Are there any standards required?*	Not relevant
	Cybersecurity	*Are there any cybersecurity requirements?*	Not relevant
Legal	Local, national of EU policy	*Does the solution support the compliance with given policies?*	The solution shows information on quality classes of reclaimed water according to EU regulation 2020/741
Governance and social	Social acceptability	*What could influence the acceptance of the solution by the utility and/or the citizens?*	The solution represents an interesting tool for the data analysis giving information about reclaimed water quality and availability, thus it is useful in increasing the citizen acceptance of water reuse
	Teamwork and responsibility	*Does the solution require specific team organizations?*	Yes, a specific team working on the platform is needed
	Required skills	*Does the solution require specific skills?*	The solution is quite simple to use, even if a specific implementation team is required
Further	/	*Further requirement?*	/

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4.5. DS5.1. Active unmanned aerial vehicle for analysis of irrigation efficiency; DS5.2 Match making tool between water demand for irrigation and safe water availability

Topics	Sub-topic	Explanation	Specific drivers and obstacles
Environmental	Precipitation pattern / rainfall	*Could the type of precipitation (intensity, frequency) influence the use of the solution?*	Yes, low rainfall amounts, and water shortage conditions would represent a driver for better monitoring water stress and irrigation efficiencies through active UAVs, as well as for wastewater reuse through the MMT.
	Climate condition and climate change	*Does local climate settings influence the successful implementation of the solution?*	Yes, the solutions would be particularly relevant where climate change projections show decreasing rainfall patterns and increasing droughts, which would highlight the need for better monitoring and management of irrigation practices and for alternative water supplies such as treated wastewater.
	Topography	*Is the topography of the city relevant for the solution?*	No.
Technical	Type of network and infrastructure	*Is the solution adapted to only specific types of networks (e.g. combined sewer)? How universal is it?*	Yes, it requires pressurized distribution systems at the outlet of wastewater treatment plants.
	Required investment, infrastructure, and material	*Does the city need to have or purchase specific assets or material to use the solution?*	Yes, investments for the development (and maintenance) of the pressurized systems may be required. On the farmers' side, investments in crop/water level sensors etc. to monitor crop status and irrigation needs would also be necessary.
	Asset condition	*Is the structural and operational condition of the local assets relevant?*	Not really.
IT	Interoperability requirements	*Does the city need specific IT infrastructure?*	No.

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	Level of digitalization	*Is a certain level of digitalization required to use the solution?*	Yes, some level of digitalization is required for effectively carrying out the monitoring practice (e.g. how to read data from sensors). Concerning the MMT, the user-friendly interfaces should help with this matter.
	Level of standardization	*Are there any standards required?*	No, there are no essential standards.
	Cybersecurity	*Are there any cybersecurity requirements?*	Only basic standard requirements.
Legal	Local, national of EU policy	*Does the solution support the compliance with given policies?*	In Europe, for example, it could help with EU Regulation 2020/741 on minimum requirements for water reuse, as well as with individual member states guidelines on this matter (i.e. related national and regional laws/norms).
Governance and social	Social acceptability	*What could influence the acceptance of the solution by the utility and/or the citizens?*	1) For citizens: guarantee that the water reuse practice is safe (i.e. that the supplied treated wastewater is sufficiently high quality, with no related health risks), which is at least partly linked with regulations; 2) For farmers: ease of use and perspective to save money / shift to more profitable crop types; 3) For utilities: perspective to save energy and reduce CO2 emissions -by tailoring the treatment process to the water quantity/quality needed by farmers, or even to make profits -by selling the treated wastewater to surrounding farms.
	Teamwork and responsibility	*Does the solution require specific team organizations?*	Not really. It should only require someone to be responsible for using the tool on the utility side (making it dialogue with the other tools in use that monitor the treated wastewater quantity and quality) and the farmer to carry out their monitoring practice and input the

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			relevant information on their crops, irrigation method, etc.
	Required skills	*Does the solution require specific skills?*	No.
Further	/	*Further requirement?*	No.

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4.6. DS6. Serious game on the water reuse-carbon-energy-food-climatic nexus

Topics	Sub-topic	Explanation	Specific drivers and obstacles
Environmental	Precipitation pattern / rainfall	*Could the type of precipitation (intensity, frequency) influence the use of the solution?*	The typical precipitation patterns are considered for the definition of the local territorial characteristics, where the player want to play the serious game
	Climate condition and climate change	*Does local climate settings influence the successful implementation of the solution?*	The typical climatic conditions are considered for the definition of the local territorial characteristics, where the player want to play the serious game
	Topography	*Is the topography of the city relevant for the solution?*	The typical topography, which may affect catchment hydrodynamic, freshwater availability and sewer network characteristics to WWTPs inflows, are considered for the definition of the characteristics of the territory where the player wants to play the serious game
Technical	Type of network and infrastructure	*Is the solution adapted to only specific types of networks (e.g. combined sewer)? How universal is it?*	The serious game is applied to a water reuse system mainly in urban/periurban areas, less usable for rural and decentralized communities
	Required investment, infrastructure, and material	*Does the city need to have or purchase specific assets or material to use the solution?*	No, except for internet connection or mobile/computer devices
	Asset condition	*Is the structural and operational condition of the local assets relevant?*	Only internet connection is required
IT	Interoperability requirements	*Does the city need specific IT infrastructure ?*	Only internet connection is required

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	Level of digitalization	*Is a certain level of digitalization required to use the solution?*	Only internet connection and mobile/computer devices are required
	Level of standardization	*Are there any standards required?*	No
	Cybersecurity	*Are there any cybersecurity requirements?*	No
Legal	Local, national of EU policy	*Does the solution support the compliance with given policies?*	The solution support science-based public awareness and engagement about circular economy action plan, water reuse, nexus and systemic/intersectoral policies
Governance and social	Social acceptability	*What could influence the acceptance of the solution by the utility and/or the citizens?*	The easy-to-use interface and the gaming approach increase the willingness of people to be informed about the systemic and intersectoral sustainability of water reuse
	Teamwork and responsibility	*Does the solution require specific team organizations?*	No, organization of public events is encouraged to spread the use of the serious game
	Required skills	*Does the solution require specific skills?*	No, the game is designed to be played by 15-99 age players
Further	/	*Further requirement?*	

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4.7. DS7. Mobile application for data collection of drinking water wells

Topics	Sub-topic	Explanation	Specific drivers and obstacles
Environmental	Precipitation pattern / rainfall	*Could the type of precipitation (intensity, frequency) influence the use of the solution?*	No, it is not relevant
	Climate condition and climate change	*Does local climate settings influence the successful implementation of the solution?*	No, it is not relevant
	Topography	*Is the topography of the city relevant for the solution?*	No, it is not relevant
Technical	Type of network and infrastructure	*Is the solution adapted to only specific types of networks (e.g. combined sewer)? How universal is it?*	The BWB well diary is adapted to groundwater well infrastructure and uses a specific connector to the internal database. The general well diary can be adapted to other infrastructure assets and use other internal datasets via custom connectors - or even be used standalone.
	Required investment, infrastructure, and material	*Does the city need to have or purchase specific assets or material to use the solution?*	Internal computing infrastructure and end-user terminals (tablets or smartphones) would be required to operate the system. Alternatively, a managed setup can be provided by VRAG.
	Asset condition	*Is the structural and operational condition of the local assets relevant?*	No, it is not relevant
IT	Interoperability requirements	*Does the city need specific IT infrastructure?*	Solution needs to be adapted to local IT infrastructure, specifically the connected database of the groundwater well operator. Alternatively, if no such database exists, the system can operate independently. Data can be imported via CSV.

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	Level of digitalization	*Is a certain level of digitalization required to use the solution?*	A central database for infrastructure is needed to interconnect with existing services. Alternatively, see interoperability requirements above.
	Level of standardization	*Are there any standards required?*	For internal data exchange, a relational database is required. Alternatively, see interoperability requirements above.
	Cybersecurity	*Are there any cybersecurity requirements?*	Yes, depending on the requirements of the user. For DS7.1 within DWC, a containerized solution was chosen that operates fully within BWBs internal networks.
Legal	Local, national of EU policy	*Does the solution support the compliance with given policies?*	The solution is able to securely document drinking water well maintenance digitally. If there is an upcoming requirement to digitally track such assets (e.g., extending to BIM in the future), the system would offer a sufficient digitization and digitalization level to do so.
Governance and social	Social acceptability	*What could influence the acceptance of the solution by the utility and/or the citizens?*	The solution was co-developed with the users and its features are therefore tailored to the specific needs of the utility. Depending on potential differences of infrastructure as well as technical procedures in other utilities, adaptations might be necessary and should include participation of the target utility.
	Teamwork and responsibility	*Does the solution require specific team organizations?*	No, it is not relevant
	Required skills	*Does the solution require specific skills?*	It requires the ability to operate a smartphone or tablet.
Further	/	*Further requirement?*	

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4.8. DS8. DTS sensor for tracking illicit sewer connections

Topics	Sub-topic	Explanation	Specific drivers and obstacles
Environmental	Precipitation pattern / rainfall	*Could the type of precipitation (intensity, frequency) influence the use of the solution?*	Depends on the application. When applied to storm sewers (searching for wastewater inflows) we filter out data collected during rainfall because it disturbs the signal. But when applied to foul sewers (searching for infiltration and inflow) the data collected during rainfall is among the most valuable!
	Climate condition and climate change	*Does local climate settings influence the successful implementation of the solution?*	Not really. Experience shows that only when the temperature of the inflows is exactly equal (within 0.2 °C) to ambient temperatures, the inflows are not detectable.
	Topography	*Is the topography of the city relevant for the solution?*	With increasing steepness of the sewer pipes, the flow velocity increases. To still be able to pinpoint the source of an inflow we need to increase the monitoring frequency.
Technical	Type of network and infrastructure	*Is the solution adapted to only specific types of networks (e.g. combined sewer)? How universal is it?*	It can be (and has been) applied to all kinds of sewer systems (storm sewer, foul sewer, combined sewer), each with the objective to find unwanted inflows into those systems. In foul and combined sewers, pollution build-up around the fiber-optic cables is important to consider and monitor.
	Required investment, infrastructure, and material	*Does the city need to have or purchase specific assets or material to use the solution?*	Yes, the application requires a dedicated DTS monitoring unit as well as fiber-optic cables that serve as long temperature sensors in the sewer system. Purchasing these items is not necessary for a pilot project (can be rented from suppliers) but is much more cost-effective for long-term application.
	Asset condition	*Is the structural and operational condition of the local assets relevant?*	Yes, the sewer systems need to be free of large sediment deposits as these can hinder the measurements.

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IT	Interoperability requirements	*Does the city need specific IT infrastructure?*	No, DTS units are stand-alone units.
	Level of digitalization	*Is a certain level of digitalization required to use the solution?*	Not relevant.
	Level of standardization	*Are there any standards required?*	The use of DTS comes without the need for ATEX-regulation (no electrical signals in the fiber-optic cables, only laser light)
	Cybersecurity	*Are there any cybersecurity requirements?*	Not relevant.
Legal	Local, national of EU policy	*Does the solution support the compliance with given policies?*	Bathing water policies, water quality policies
Governance and social	Social acceptability	*What could influence the acceptance of the solution by the utility and/or the citizens?*	Improving local water quality, enhancing options for bathing in natural waters
	Teamwork and responsibility	*Does the solution require specific team organizations?*	A team needs to be able to (1) install and maintain fiber-optic cables in a sewer system and (2) collect and analyse DTS measurement and translate these into useful results.
	Required skills	*Does the solution requires specific skills?*	Analysis and interpretation of DTS measurements requires some experience to be built up over several projects.
Further	/	*Further requirement?*	

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4.9. DS9. Sensors and smart analytics for tracking illicit sewer connections hotspots

Topics	Sub-topic	Explanation	Specific drivers and obstacles
Environmental	Precipitation pattern / rainfall	*Could the type of precipitation (intensity, frequency) influence the use of the solution?*	Since the solution is based on water quality monitoring, heavy rainfall instances that highly dilute sewer streams could influence the detection of quality changes. Yet, this high dilution would also mean there is less likelihood of bacterial contamination of the receiving water bodies. When precipitations are less frequent and intense, the solution can easily detect the patterns of sewer discharge.
	Climate condition and climate change	*Does local climate settings influence the successful implementation of the solution?*	There is no specific influence of local climate settings.
	Topography	*Is the topography of the city relevant for the solution?*	The topography has little influence on the implementation and operation of the solution. Integrating knowledge of the topography could help in the planning and analysis phase but is not necessary.
Technical	Type of network and infrastructure	*Is the solution adapted to only specific types of networks (e.g. combined sewer)? How universal is it?*	In the project, the solution addresses a challenge that is solely relevant to separate sewer systems, however, the technology can be implemented in other types of networks.
	Required investment, infrastructure, and material	*Does the city need to have or purchase specific assets or material to use the solution?*	No, since Kando's business model in most of the cases is "Solution as a Service". Kando provides installation, maintenance, and analysis of the data so that the client can watch insights about his network provided to his dashboard.
	Asset condition	*Is the structural and operational condition of the local assets relevant?*	The solution is combined of hardware, mostly installed in manholes and pump stations, and software. The hardware is easy to install and commission and has a small footprint. It can be installed even in challenging manhole conditions.

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IT	Interoperability requirements	*Does the city need specific IT infrastructure?*	Not at all, since the data transmission is telemetry, and the software access is cloud based.
	Level of digitalization	*Is a certain level of digitalization required to use the solution?*	GIS drawings of the network, even partial, are required for a successful project. Other than that, the solution is cloud based with web access and not interfacing with the client's SCADA system.
	Level of standardization	*Are there any standards required?*	No standards are required from the client's point of view. Kando comply with ATEX standards if the client requires.
	Cybersecurity	*Are there any cybersecurity requirements?*	There are no requirements, and Kando follows the highest industry standards for security such as ISO 27001, protecting against attacks in various tactics such as Denial of Service (DDoS).
Legal	Local, national of EU policy	*Does the solution support the compliance with given policies?*	The solution supports compliance with urban and industrial wastewater treatment policies (Council Directive 91/271/EEC), as well as pretreatment program policies
Governance and social	Social acceptability	*What could influence the acceptance of the solution by the utility and/or the citizens?*	The acceptance of the solution could be accelerated by compliance with regulation objectives, public image objectives, circular economy objectives, operational issues (WWTP upsets, odor issues, etc.)
	Teamwork and responsibility	*Does the solution require specific team organizations?*	The solution does not require specific organizational requirements. On the contrary, the solution supports smoother communications between different departments and levels. The solution provides different dashboards to different stakeholders (network operators, WWTP operators, environment compliance teams, directors)
	Required skills	*Does the solution require specific skills?*	The solution is easy to learn and manage, and is supported by a Customer Success Manager to lead through the insights and support decision making.

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4.10. DS10. Augmented Reality (AR) mobile application for groundwater visualisation

Topics	Sub-topic	Explanation	Specific drivers and obstacles
Environmental	Precipitation pattern / rainfall	*Could the type of precipitation (intensity, frequency) influence the use of the solution?*	No
	Climate condition and climate change	*Does local climate settings influence the successful implementation of the solution?*	No
	Topography	*Is the topography of the city relevant for the solution?*	Yes, as a resource to model overview and scenario scenes.
Technical	Type of network and infrastructure	*Is the solution adapted to only specific types of networks (e.g. combined sewer)? How universal is it?*	No
	Required investment, infrastructure, and material	*Does the city need to have or purchase specific assets or material to use the solution?*	It needs to provide geological, geohydrological and groundwater flow data.
	Asset condition	*Is the structural and operational condition of the local assets relevant?*	No
IT	Interoperability requirements	*Does the city need specific IT infrastructure?*	No, need resources to prepare groundwater flow models using MODFLOW.
	Level of digitalization	*Is a certain level of digitalization required to use the solution?*	Digital models of groundwater flow, geology, geohydrology are required.
	Level of standardization	*Are there any standards required?*	MODFLOW 2005 for groundwater modeling

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	Cybersecurity	*Are there any cybersecurity requirements?*	No
Legal	Local, national of EU policy	*Does the solution support the compliance with given policies?*	Not relevant
Governance and social	Social acceptability	*What could influence the acceptance of the solution by the utility and/or the citizens?*	Solid UX, performance on end devices must be adequate, the narrative flow fulfills user demand
	Teamwork and responsibility	*Does the solution require specific team organizations?*	No, but it can be used by tour guides in water works to present the app to tour customers, e.g. pupils or children
	Required skills	*Does the solution require specific skills?*	It requires the ability to operate a smartphone or tablet.
Further	/	*Further requirement?*	

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4.11. DS11. Sewer flow forecast toolbox; DS12. Interoperable DSS and real-time control algorithms for stormwater monitoring; DS13. Web platform for integrated sewer and WWTP control

Topics	Sub-topic	Explanation	Specific drivers and obstacles
Environmental	Precipitation pattern / rainfall	*Could the type of precipitation (intensity, frequency) influence the use of the solution?*	The solution is primarily for systems, where there are issues with combined sewer overflows, flooding, and high inflow rates to the treatment plants, due to high rain intensity
	Climate condition and climate change	*Does local climate settings influence the successful implementation of the solution?*	The specific climate conditions are relevant for defining and adapting the functionality of the tool. Is the main problem excess rain and CSO/flood, is it high loads on WWTP, is it high water levels in the receiving water?
	Topography	*Is the topography of the city relevant for the solution?*	Not really
Technical	Type of network and infrastructure	*Is the solution adapted to only specific types of networks (e.g. combined sewer)? How universal is it?*	System creates values for separate as well as combined sewer system
	Required investment, infrastructure, and material	*Does the city need to have or purchase specific assets or material to use the solution?*	The city needs a functional SCADA system, with info on rain (from gauges or radar), flows, levels at critical point. If the system includes operational devices, the operation of these may be optimized
	Asset condition	*Is the structural and operational condition of the local assets relevant?*	Yes. Generally, the system shall work as described. If control devices are available, these may be included for optimal control
IT	Interoperability requirements	*Does the city need specific IT infrastructure?*	Not really. The solution can be implemented on premise or as a cloud solution.
	Level of digitalization	*Is a certain level of digitalization required to use the solution?*	The basic functionality requires access to historical data for rain and inflow to treatment plant (for training the Machine Learning algorithm) and real-time rain data for operation use.

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	Level of standardization	*Are there any standards required?*	No standards required, but access to data from SCADA systems are needed
	Cybersecurity	*Are there any cybersecurity requirements?*	The system does not require special security conditions, but will work within the rules and limitations required by the end-user
Legal	Local, national of EU policy	*Does the solution support the compliance with given policies?*	The system may assist the utility to meet the Bathing Water Directive and European and national water quality requirements
Governance and social	Social acceptability	*What could influence the acceptance of the solution by the utility and/or the citizens?*	The system assists in reducing pollution and energy consumption
	Teamwork and responsibility	*Does the solution require specific team organizations?*	Although running automatically, the system needs attention and ownership. The weaker points are related to the data flow, if input data stop for some reasons, the system will not run. The system includes alerts, for missing data
	Required skills	*Does the solution requires specific skills?*	Only skills already available at the professional staff
Further	/	*Further requirement?*	If the city already has (or plan to have) hydraulic models, these models can add further value to the solution

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4.12. DS14. Low-cost temperature sensors for real-time CSO and flooding monitoring

Topics	Sub-topic	Explanation	Specific drivers and obstacles
Environmental	Precipitation pattern / rainfall	*Could the type of precipitation (intensity, frequency) influence the use of the solution?*	Not at all
	Climate condition and climate change	*Does local climate settings influence the successful implementation of the solution?*	Not at all
	Topography	*Is the topography of the city relevant for the solution?*	Not at all
Technical	Type of network and infrastructure	*Is the solution adapted to only specific types of networks (e.g. combined sewer)? How universal is it?*	Relevant for all cities with combined sewer systems and experiencing overflow events.
	Required investment, infrastructure, and material	*Does the city need to have or purchase specific assets or material to use the solution?*	No need of additional material. There might be some Issue of installation and maintenance compared to traditional water level sensors
	Asset condition	*Is the structural and operational condition of the local assets relevant?*	Not at all, the solution works potentially in any kind of sewer infrastructure
IT	Interoperability requirements	*Does the city need specific IT infrastructure?*	It works with usual GPRS network, but if desired, the use of the online solution can require the availability of a LORAWAN network
	Level of digitalization	*Is a certain level of digitalization required to use the solution?*	Yes, but minor. The solution can work both with an independent web platform interface or be integrated with existing systems through a 3rd party API.
	Level of standardization	*Are there any standards required?*	It exchanges and communicate data is JSON format. But can easily be integrated with existing systems through a 3rd party

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			API which allow access to data in compatible formats.
	Cybersecurity	*Are there any cybersecurity requirements?*	No
Legal	Local, national of EU policy	*Does the solution support the compliance with given policies?*	Solution only delivers occurrence and duration of the overflows, no volume: can be limiting for compliance purposes
Governance and social	Social acceptability	*What could influence the acceptance of the solution by the utility and/or the citizens?*	The main criteria would be 1) ease of maintenance, 2) frequency of maintenance, 3) accuracy
	Teamwork and responsibility	*Does the solution require specific team organizations?*	Requires local field team just to install and maintain during operation.
	Required skills	*Does the solution require specific skills?*	No, only basic operations-maintenance skills.
Further	/	*Further requirement?*	

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4.13. DS15. Smart sewer cleaning system with HD camera and wireless communication

Topics	Sub-topic	Explanation	Specific drivers and obstacles
Environmental	Precipitation pattern / rainfall	*Could the type of precipitation (intensity, frequency) influence the use of the solution?*	Not at all
	Climate condition and climate change	*Does local climate settings influence the successful implementation of the solution?*	Not at all
	Topography	*Is the topography of the city relevant for the solution?*	Not at all
Technical	Type of network and infrastructure	*Is the solution adapted to only specific types of networks (e.g. combined sewer)? How universal is it?*	The solution can be used for the inspection of separate and combined sewer networks.
	Required investment, infrastructure, and material	*Does the city need to have or purchase specific assets or material to use the solution?*	The city needs to purchase Xpection lite; the new version works as a standalone device.
	Asset condition	*Is the structural and operational condition of the local assets relevant?*	The solution supports utilities in assessing cleaning needs and identifying sewer defects in a timely manner without CCTV inspection.
IT	Interoperability requirements	*Does the city need specific IT infrastructure?*	No, the solution is standalone
	Level of digitalization	*Is a certain level of digitalization required to use the solution?*	No
	Level of standardization	*Are there any standards required?*	No; the solution does not provide defect coding of sewer defects and thus does not rely on a standard.

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	Cybersecurity	*Are there any cybersecurity requirements?*	/
Legal	Local, national of EU policy	*Does the solution support the compliance with given policies?*	The solution improves the management of sewer network and thus support compliance with the water framework directive WFD and Urban Waste Water Treatment Directive UWWTD.
Governance and social	Social acceptability	*What could influence the acceptance of the solution by the utility and/or the citizens?*	/
	Teamwork and responsibility	*Does the solution require specific team organizations?*	The solution requires a team with 2 operators along with a cleaning truck
	Required skills	*Does the solution require specific skills?*	A training of 2-3 hours is necessary to be able to use the solution independently.
Further	/	*Further requirement?*	/

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5. Conclusion and lessons learnt

DWC has developed and brings to the market a series of 15 digital solutions, easily accessible on the digital-water.city website. During the project, all solutions have been tested in full scale in five cities: Berlin, Copenhagen, Paris, Milan and Sofia.

This document aims to **summarize the main drivers, obstacles and requirements for transferability and replicability** of the 15 digital solutions developed within DWC. In particular, it assesses key operational (e.g. local challenges and management practices, etc.), organizational (e.g. local ICT governance and system interoperability) and technical conditions (e.g. type of network, precipitation pattern, etc.) for a successful implementation of the solution. The outcomes can be used as a checklist for new utilities to assess potential for local deployment.

These solutions aim to face the challenges of the water sector such as human health protection, performance and improvement of infrastructures, ensure return on investment, the necessary public involvement, and acting on governance, interoperability and cybersecurity. By listing criteria to be taken into account in transferability (transversal themes regardless of location, such as team requirements, governance, cybersecurity etc.), and those that can only be contextualized or site-specific, this analysis of the 15 solutions developed by DWC make it possible to assess the "replicable" nature of these solutions so that other cities can evaluate the relevance and usefulness while implementing these solutions in their own context.

Even if this document does not aim at outlining general requirements for transferability, the analysis of the outcomes allow us to map the **five key obstacles for the uptake** of DWC digital solutions, summarized as follows.

Regulation and legislative support. While there are general EU regulatory frameworks, they are implemented differently and local regulations depend on each country. The Water Framework Directive and related directive (e.g. Bathing Water Directive) do not include legal requirements on the use of online monitoring, sensor systems, predictive maintenance, modelling tools. The compliance of the directives generally does not rely on the state of the art of digital solutions, restraining the digitalization of the entire sector. For example, there are no general European standards on approved methods for bathing water monitoring. While it is common knowledge among bathing water quality managers, that results obtained by manual grab sampling and laboratory analysis are too slow to day-to-day bathing water quality management, the current European Bathing Water directive does not directly support the use of prediction modeling and real-time analytical approaches for decision making.

Data requirement. A key obstacle for the uptake of digital solutions and in particular modelling approaches is sufficient data availability. For making correct predictions, machine learning models require informative data on the entire variability of states of the observed systems. Data collection and management is a key part to ensure the successful uptake of digital solution. Beside data availability, the reliability and qualitative variability of real-time data is also a key factor that can influence the performance of digital solutions and thus their relevance for the end-users. Ensuring data quality can lead to very relevant efforts (data cleaning, outlier detection, etc.) and thus delay or hamper the implementation.

Deployment costs. While digital solutions can provide substantial benefits in reducing OPEX and CAPEX in managing water along the water value chain, the acquisition, deployment, integration and maintenance of digital solutions can represent large expenses for utilities. Even open source solution

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induce a series of costs for the user to ensure semantic interoperability, its successful integration in the company processes and its proper operation and maintenance. In some cases, costs might reduce in the future along with upscaling (e.g. the creation of a volume market for sensing technologies). In other cases, return on investment are not immediate and need to be better demonstrated, quantified and communicated. Finally, the willingness to invest in digital solutions requires a strong and long-term drive to solve urban water management issues, in particular in the light of missing legislative support.

Digitalization level. The low digitalization level of some utilities, in particular, smaller operators of water infrastructures, can hinder the applicability of digital solutions relying on a specific IT infrastructure or on the availability of large datasets. For example the uptake of real-time control solutions require the availability or development of calibrated hydraulic model of the networks. The integration of modelling approaches between networks and treatment plants requires interoperability between systems. Regarding water reuse and precision farming, the uptake of digital solutions calls for a shift in practices, where farmers other than investing in sensor systems also start interacting with the tool in their practice. In some cases, the uptake of digital solution is not hindered by technical limitations but by organisational challenges. Digital solutions often require data sharing across organisations and departments to ensure their successful use but also the consideration of the outcomes into the decision making process of the end-users.

Trust. The low trust on the outcomes or reliability of digital tools along with the lack of standardization can make the results not usable or acceptable by authorities and end-users. DWC has contributed to this increase the trust for digital solutions by demonstrating the tangible benefits of digital solutions over a range of applications. However, for new applications, the lack of local data, the dependence to local boundary conditions and the inherent uncertainties associated with modelling approaches systematically raise the question of the reliability of the outcomes. The growing uptake of digital solutions and the increasing number of successful business cases are expected to create a fertile ground to improve the confidence in digital tools for the water sector.

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