digital-water.city

2019-2022

Project Summary

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Factsheet

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Grant Agreement Number	n° 820954
Instrument	HORIZON 2020
Start date of the project	01 June 2019
Duration of the project	42 months
Website	www.digital-water.city
Delivery date	2023-04-01

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Executive summary

Summary of the context and overall objectives of the project

Europe's waters are under mounting pressure. Agricultural and industrial activities as well as increased urbanisation trigger pollution, over-abstraction and modification of water bodies. Today, almost three quarters of Europeans (EU and non-EU countries) live in urban areas, with an increasing trend that is projected to reach more than 80% by 2050.

To face current and future challenges, digital technologies are acknowledged as key enabler to improve water management. Powerful digital technologies such as mobile devices, sensor networks, real-time monitoring, cloud computing, machine learning, and modelling tools have the potential to improve dramatically the management of water infrastructures. The water industry of the future is expected to be digital, smart and resource-efficient. Utilities will embrace this change and become more efficient and resilient by unleashing the value and free flow of data and the new perspectives provided by big data solutions. However, this promising scenario is still restrained by (1) the lack of business cases and tangible evidences of the benefits provided by digital solutions across the water value chain and (2) the low level of maturity of digital solutions regarding standardization, interoperability, cybersecurity and governance aspects. The high need for investment in water infrastructures is a real chance to accelerate dramatically the connection between the current physical and digital worlds.

Within this context, DWC's main goal is to boost the integrated management of waters systems in five major European urban and peri-urban areas – Paris, Berlin, Copenhagen, Milan and Sofia – by leveraging the potential of data and smart digital technologies. The assessment and communication of the benefits provided by digitization aims at raising the awareness of European cities for a necessary digital transformation and at fostering the large-scale market uptake of digital solutions in Europe.

Progress beyond the state of the art and potential impacts

Technical development and demonstration of 15 digital solutions

DWC's ambition was to be a 'lighthouse' project for digital solutions building stronger links between the physical and digital worlds. At its core, DWC have focused on the development, demonstration and assessment of the benefits of 15 digital solutions. These solutions addressed three main challenges of urban water management, namely the protection of human health, the performance of water infrastructures and the public involvement on water management. The development of the digital solutions has been kicked off at the beginning of the project and made great progress since. All solutions have been improved and tailored during the project in close cooperation with the city partners. Finally, the solutions have been deployed locally in our five city case studies and their potential has been assessed thanks to a series of performance indicators.

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The following figure presents the solutions, their role on the water cycle and the type of digital solutions at stake.

Figure 1 Panel of digital solutions developed within DWC

The table in the last section of this executive summary summarizes for each solution: 1) the challenges addressed, 2) the technical solution, 3) the benefits obtained from the local demonstration, 4) the innovation beyond state of the art and 5) the foreseen impacts beyond the project.

Key innovations of DWC against the state of the art of urban water management are presented briefly below.

1 Real-time water quality monitoring and early warning

DWC has developed new technologies for fully automated water quality monitoring. The innovation of the new ALERT system consists in the possibility to perform online measurements on E.coli and Enterococci concentration halfing the response times and minimizing handling and transportation while providing a similar accuracy as the laboratory (DS1 ALERT system).

DWC have brought to the market a new generation of data-driven early warning system. The EWS for bathing water management allows to reach an accuracy of 95% to predict days with

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insufficient water quality (DS2 SWIM:AI). The modeling platform enables stakeholders to train ML models and use them for daily bathing water quality predictions. Thereby, it addresses one of the major barriers of bathing water quality management, namely that current analytical methods are not suitable to timely inform bathers about impaired water quality.

2 New capacities for sewer monitoring and WWTP management

DWC has developed a new low-cost monitoring solution for combined sewer overflow (DS14). The precision is similar to traditional flow sensors and equipment costs are reduced by 70%. It allows utilities to monitor precisely a vast amount of CSO outlets with affordable expenses. DWC has also highlighted the relevance of sensors to tackle illicit connections. A new DWC methodology (DS9) has proven to be 10 times more efficient than conventional visual inspection (e.g. manhole inspection) to narrow down hotspots of illicit connections in the network. Respectively, monitoring costs have proven to be 2/3 less expensive than visual inspection. The DTS technology (DS8) is able to pinpoint illicit connections to their exact location in the sewer but costs are around 3.5 times more expensive than conventional visual inspection.

DWC did not explore only the role of sensors for sewer management but also highlighted the relevance of machine learning for sewer flow modelling (DS10). The accuracy for short-term inflow forecast could be increased by 30% compared to hydrodynamic models. The accuracy of long-term forecast compared to measured rain data was in the range of 70-80%.

The potential of sensors and machine-learning has been embedded in a new real-time control solution for the integrated management of sewer networks and WWTP (DS11). It allows to save 25% of sewer bypass volume and 20% of nitrogen emissions. Obtaining an equivalent effect through new storage volume at the WWTP would cost the utility around 75 M€ investments.

3 Advanced decision support on water reuse risks

DWC developed a new service for wastewater treatment plant aimed at preventing bacterial and toxic contamination linked to the reuse of treated wastewater for agricultural irrigation (DS3). The tool is able to identify the occurrence of a contamination event in real-time within the framework of risk assessment and management provided by the European Regulation 741/2020, and is able to identify the suitable uses of the reclaimed water, according to the quality classes defined by this legislation.

To foster water reuse from the farming side, DWC has developed a new drone solution (DS5.1) based on the combination of three technologies for remote detection of water stress: 1) ground sensors, 2) unmanned aerial vehicles with spectral imagery and 3) satellites. Finally, DWC deployed a web-based application to manage demand for treated wastewater for agricultural irrigation (DS5.2). The platform will be used as a communication tool to inform farmers about the possible water supply and to inform wastewater treatment plant managers about the current irrigation needs.

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4 Interoperability and cybersecurity

It is worth mentioning that DWC innovation does not rely only on the availability of new technological tools: major progresses have been achieved in the necessary integration of digital solutions within existing IT systems through the harmonization of data models, the use of FIWARE as reference architecture for smart city solutions and new approaches for exploring cyber risk. In order to achieve semantic interoperability between data, model and systems, DWC has proposed new ontology extensions to ETSI in order to consider DWC requirements and to contribute to the development of global and widely applied ontologies. DWC has also enhanced the FIWARE ecosystem by providing a semantic interoperability software as a standalone component (as well as solutions compatible with FIWARE).

Regarding cybersecurity, DWC builds on the results of the H2020 project STOP-IT which has been entirely focused on increasing the cyber and physical protection of the water sector. DWC has extended the stress-testing methodology to the wastewater sector and produced a risk management guide, in which for each step of the risk management process, the user can find an overview of the approaches, methods, tools to be used to protect water infrastructure against cyber-physical threats. DWC also achieved a web-based database including 68 type of risk events specific to sewer management. Finally, DWC has developed a set of security checklists supporting both technology providers and water utilities.

Digital integration and market uptake

Digitalization is not only about technological development. As we seek the full integration and uptake of DWC solutions, specific activities were conducted to address the existing gaps of digital water regarding stakeholder involvement, data governance, interoperability, cybersecurity and market uptake.

Community of practice

The establishment of Communities of Practice (CoPs) has been the binding element (our DWC "cement") to achieve a truly interdisciplinary and transdisciplinary approach. CoPs have been established locally in the five cities which have hosted regular workshops to build trust and consider the expectations of local stakeholders within the development of the digital solutions.

The process of co-creation within COPs has succeeded in bringing together a wide range of actors from the public and private sectors, research and industry, municipalities and authorities. A major difficulty was to engage regularly and seriously all stakeholders in the co-creation process, when the availability of participants is limited and the output of the co-creation process is not immediately tangible. A strong involvement of the local organizers (DWC utilities) and intense bilateral communication with the stakeholders to prepare the events were essential for the success of the initiatives. Key output of the co-creation process was the clear elicitation of the needs of the end-users, integrating the point of views and vision of innovators, researchers, utilities, authorities and end-users. As a result, the process allowed to consider these needs into the technical development of the solutions and also to build trust

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in the future uptake of the solutions. For example, in Paris, the COP has supported the development of two digital applications for bathing water management. All stakeholders involved in the management of bathing water for the Olympic game of 2024 as well as future bathing sites in the Paris region were gathered monthly to discuss the development and future use of such applications (e.g. sewer utilities, bathing site managers, health authorities, etc.). The collaboration has led to the design of applications that clearly respond to the needs of the stakeholders (starting by the identification of compromises for these needs) and created a common ground for the future use and development of these applications. The CoP will follow up its activities beyond the project, ensuring the uptake of the digital solutions by the future bathing site managers and channeling future R&D needs when necessary.

At project level, a special community of practice has fostered interactions between the city partners and facilitated knowledge exchange on key challenges. The CoP was the opportunity for the cities to exchange their experiences regarding the development of digital solutions, while comparing these innovations to current solutions used to address similar problems. The CoP has also provided a space for discussion around cross-cutting topics (such as cyber-security, interoperability, digital governance etc.), where technical partners and DWC cities met and shared doubts and experiences.

Governance

Another key task of DWC was to assess the local governance settings and facilitate the uptake of the solutions. Main activity was the development of a governance assessment framework to identify non-technical factors relevant for the successful implementation of digital solutions. The governance settings as well as the stakeholder's viewpoints, claims and expectations have been largely explored during interviews, field investigations, focus groups and community of practices. As key outcomes, governance fragmentation and path dependencies of technical and political nature clearly constrain digitization initiatives. Consequently, changes occur incrementally rather than in an encompassing manner. Legal uncertainty and cost-effectiveness emerged as discouraging actors to invest in digital solutions. In many cases, outdated legal framework that leaves normative gaps hinder innovation uptake. Finally, the characteristics of water infrastructure as critical infrastructure was also identified as general barrier as potential security risks might arise. Risk aversion and low levels of digital literacy of water managers can be a complicating factor.

Policy

A policy matrix has also been developed to screen policies affecting digital water management and governance. The scope of the matrix has been extended to the five sister projects (DW2020 group formed by digital-water.city, ScoreWater, Fiware4Water, NAIADES and aqua3s) which have cooperated to develop a common policy brief for digitalization in the water sector. The policy brief published in November 2022 by the European commission provides an overview of current gaps in the EU legislative framework that hinders the potential of digitalisation in the water sector and provides concrete recommendations on how to overcome these. Main suggestions are to

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- Harmonize online monitoring standards in particular for pollutants from sewer networks and combined sewer overflows
- Foster the creation of a volume market for sensing and modelling technologies,
- Enforce the use of proven sensors and modelling systems into existing regulations (e.g. bathing water directive)
- Ensure semantic interoperability between digital solutions
- Encourage information sharing about threats to cybersecurity
- Promote the use of digital solutions for environmental education

Cybersecurity and interoperability

DWC has focused on the integration of digital solutions within existing systems, addressing interoperability and cybersecurity issues. Main activities include the definition of requirements to be addressed by local interoperability middleware and semantic models as well as the development of new ontology classes for the SAREF suite. The work has been closely aligned with the published SAREF ontologies (notably SAREF4WATR) and the FIWARE reference architecture, which has been tested in two case studies to ensure semantic interoperability. A risk identification database has been designed to list potential cyber threats along the water value chain. This contribution has been used as a starting point to perform a stress testing of a wastewater infrastructure subjected to a cyber-attack.

Market uptake

Market activities have been conducted in two tracks: a first track focuses on SME using the MAF+ portal to evaluate and compare the attractiveness of different market segments and define the main target group that will be addressed by the digital solutions.

A second track addresses solutions developed by non-commercial partners (e.g. universities) with the aim to assess their business potential and to set the scene for the creation of startup and the future commercial exploitation of our most promising innovations. Business development activities have led to the creation of two new spinoff/services with a clear roadmap beyond the end of the project.

The first service is called SWIM:AI and relates to the early warning system for bathing water deployed by KWB in Berlin. SWIM:AI is a software application built on open source technologies designed to support communities in more effectively monitoring the water quality of their bathing sites and ensuring the health of the bathers. The service consists in the development and implementation of data-driven models for a real-time risk-based assessment of bathing water quality. The open source business model not only makes the solution more accessible to municipalities, but it also guarantees increased trust and flexibility, as the customer is able to understand SWIM:AI's inner workings and freely adapt the model to optimally suit their needs. The solution is powered by FIWARE, which guarantees easy integration with other solutions and platforms also based on the Orion Context Broker.

The second service is called SUSAWARE and relates to the early warning system for water reuse deployed by UNIVPM in Italy. The Early Warning System (EWS) is able to detect the

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occurrence of a contamination or hazardous event at the wastewater treatment plant in real time or even in advance to improve the protection of public health and the environment. The solution is designed to combine risk management and digitalization. The EWS is a digital tool that analyzes data from an integrated network of sensors and softsensors and issues alerts and warnings so that treatment plant personnel can respond immediately and take preventive measures that ensure the safe reuse of wastewater. The solution is complemented by a consultancy service, to be offered before the implementation of the EWS and aimed at the identification of hazards/risks in water reuse and at designing a risk management plan according to EU regulation 2020/741. This is a mandatory requirement for a water reclamation facility to implement water reuse.

Communication

Communication and dissemination activities have also been carefully conducted, including the creation of our website (>22,000 visits) and visual identity, the management of social media (>900 followers on LinkedIn), the participation to professional events and conferences (> 60; see video of our closing event), scientific publications (> 45), the development of promotional videos and visuals, etc. Finally, DWC launched and leaded the synergy group DigitalWater2020 (DW2020) with our five sister projects.

The creation and the activities of the DW2020 Synergy Group have demonstrated that a close collaboration among projects with common themes and topics is beneficial for the EC, the projects and ultimately for the wider public. This collaboration led to relevant outcomes, which are expected to have a wider impact than each project separately. In particular the importance of the data models created by the five projects together are expected to be useful and applicable by several other projects. The policy brief published in 2023 to highlight recommendations for digital water would not have been possible without a close collaboration between the projects. DW2020 is expected to have a lasting effect for the ICT4WATER cluster future activities and in particular the revised Digital Water Action Plan (under revision). The end of the sister projects entails also the end of the DW2020 synergy group, but the continuation of the activities will be taken over by the Action Groups of the ICT4WATER cluster.

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Gaps and recommendation

The project has highlighted key gaps and recommendations to follow up the digital water journey. These recommendations address concrete issues related to policies, R&D programs and training of water utilities.

Type	Gap	Recommendation
Policy	Specific requirements from the Member States, that could be applied in addition to the EU regulation 741/2020, could affect the **effective implementation of water reuse** and its attractiveness for water utilities. Very stringent standards or lack of incentives may reduce interests in water reuse.	Water reuse applications could be boosted by EU incentives targeted to increase a sustainable use of water resources. The use of digital solutions for risk management should be encouraged, since they could allow continuous monitoring and pro-active actions in case health risks are detected.
Policy	There is a lack of **regulations for online pollution** monitoring to enable the adoption of proven innovations for water quality monitoring. There is therefore little motivation for utilities and other actors to invest in sensing technologies and undertake large-scale surveillance campaigns. Similar conclusions could be drawn for urgent issues related to stormwater monitoring, combined sewer overflows, bathing water quality or predictive infrastructure maintenance.	Enforce the use of proven sensors and modelling systems into existing regulations (e.g. bathing water directive). Specifications on how to integrate forecasting models with standard monitoring may be provided
Policy	The improved data capacity on environmental parameters is not being used comprehensively. Although improvements in data capacity are slowly being driven by **advances in digital technologies and their rollout** into river basin management, industrial processes, and domestic water use, their potential is far from being fully realized. Sensor and modelling technologies have the potential to	Harmonize online monitoring standards in particular for pollutants from sewer networks and combined sewer overflows. This could also help advance the monitoring and enforcement capacity of the relevant authorities to support compliance with the Zero Pollution Action Plan and provisions such as the full cost recovery and polluter pays principles of the WFD and the implementation of the UWWTD.

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Type	Gap	Recommendation
	improve our understanding of water systems and dramatically improve water management. However, the prerequisites or instructions for their use are mostly lacking.	
Policy	The **water market is fragmented** and lacks standardization. It is made up of numerous utilities of varying sizes, each with unique problems in need of tailor-made solutions. The digital solutions market is itself fragmented.	Stimulate the creation of a volume market for sensing and modelling technologies. The upscaling of a fragmented market is a major barrier for many of the digital technologies in the water market. Initially, the focus should be placed on areas of the water sector where the greatest demand could be expected and where the motivation is strongest. This includes for example the optimization of capital expenditures (CAPEX) and operating expenses (OPEX).
Policy	The sector is characterized by **data exchange and interoperability issues**. In the water sector, there are different ways of exchanging data and different national and local semantic definitions of data that need to be improved. Thus, issues with data exchange and interoperability remain a key challenge to the uptake of digital solutions. In addition, data-sharing trustworthiness remains a challenge. The ability to share data has relatively little support from stakeholders due to the lack of trustworthiness of the information.	Actively engage with relevant organisations to develop relevant standards and ensure semantic interoperability. Standardisation is an important instrument to facilitate the deployment of solutions for smart water management. Complementary efforts need to be made to ensure a comprehensive set of standards and these standards shall be explicitly mentioned to be used in the EU water legislation (e.g. WFD, UUWWTD, DWD, BWD, etc).
Policy	A broader **social awareness on digitalization** in the water sector is needed. As the topic of digital water management and governance is only emerging, most stakeholders are not aware of the importance and implications of introducing digital solutions in the water sector. Current	Further explore specific situations in which digital solutions can foster public involvement and support policy goals (short and long term). Where feasible, stakeholders should be involved in a transparent process of co-creation, implementation, and post-implementation analysis of a wide range of policies. These

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Type	Gap	Recommendation
	approaches to raise social awareness focus more on targeted stakeholders and less on citizen engagement.	processes will serve to build cohesive, inclusive and, most importantly, sustainable policies using bottom-up approaches to support the adoption of policies that are society-driven. These include the potential to include guidelines on using digital solutions to foster public involvement in the River Basin Management Plan (RBMP) processes. The use of community-based Digital Social Platforms (DSPs) of Local Enabling Spaces (LES) established at regional level can be a part of the river basin management plan actions and would help build consensus and enable citizen involvement by making use of digital tools to foster their social capital and boost their societal impact in terms of innovation, knowledge transfer and business success. With regards to standardisation, agile methods based on user experience could foster direct user involvement.
Policy	**Digital literacy** within water utilities and administration is oftentimes insufficient.	Create competence development programmes on advanced data management for the water sector at regional and/or local scale and coordinate them at the EU and river basin levels.
R&D and uptake of water utility	Raw data from monitoring networks of meters and sensors require to be elaborated in order to extract accurate results from data-driven analysis. Nowadays many data from WWTPs are available thanks to technology progresses and the spreading of a wide network of sensors and meters. However, these **data are still widely underutilized** in part due to a lack of background knowledge in the field of data science, and in part due to issues related to	Further research should be addressed to develop robust and reliable sensor devices. Research activities may be addressed to develop more advanced algorithms to detect outliers and clean sensors signal. Knowledge on the elaboration of big data should be transferred to water utilities

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Type	Gap	Recommendation
	the reliability of sensors measurements	
R&D	The **use of digital solutions for water reuse** (e.g. early warning system) requires optimization and its replicability needs to be tested in other WRFs, which may have different size and a different treatments train for the reclamation of water.	Research should be addressed to optimize predictive algorithms and digital twin models for water reuse and risk management. The applicability of these predictive models needs to be validated in various water reclamation facilities.
Uptake	Several **data-driven asset management solutions** exist on the market to improve and optimize the rehabilitation and investment planning processes for a range of assets: network, wells, pumps, treatment plants, etc. Most of these models remain in the academic field and failed to support effectively utility investment planning.	Future researches should focus on demonstrating the transferability and relevance of asset management solutions in different contexts. Focus should be done on collaboration and return on experience. Large EU investment funding programs should request or mention the use of data-driven solutions to optimize asset management strategies.
Training	There is currently a **gap in digital knowledge** in general and specifically in cybersecurity in the water sector operation and EU-water legislation. The knowledge gaps are both potential sources of risks and barriers for the process of digitalization.	For the development of proper prevention and response strategies it is essential to increase cybersecurity awareness, education, training and best practices within the water industry in combination with technical security measures and embed these requirements into the EU water legislation. Furthermore, training activities on cyber security for water operators at different decision levels for an effective and adequate response should be promoted. The training should be based on core courses, augmented by a training programme involving discussion and operational exercises based on realistic and plausible scenarios. The training material developed by DWC in WP4 could be adopted by University to create a teaching module for engineering studies as well as sample material for the

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Type	Gap	Recommendation
		development of accreditation schemes of water operators (as course for beginners).
R&D	Stress-testing approaches for water distribution systems have been developed in past H2020 projects (e.g., STOP-IT) and a risk management guide to generalize the approach has been developed in DWC, using a WWTP as use case. However, current **risk-based stress-testing approaches are limited** as they only are intended to identify system components that fail under various stress loads. They lack a system-thinking, a global integrated security context, physical and cyber, and consideration of interconnectedness between system domains which can facilitate resilience stress testing. Furthermore, Stress-testing platforms, often developed in silos for individual sectors are not easily usable for stress testing within other sectors.	Stimulate R&D funding (e.g. EC or National programmes) specifically addressing the need for multi-sector stress-testing platforms enabling the modelling and the simulating of complex interactions among different physical assets and relevant technical and social systems considering multiple levels of interdependencies and cascading effects. The resulting modeling solutions will facilitate the Member States in implementing the new CER Directive since they will provide direct input for its technical annex/es.
Uptake	in line with the gap related to "cybersecurity awareness" above, there is also the need to **guide the water utilities as well as the technology providers in performing security tests** before adopting new solutions (water utilities side) or before selling them (technology provider side). This requirement is also strongly linked with the NIS 2 directives recommendations related to the security check along the entire supply chain.	WP4 has developed a list of security recommendations to be followed by digital solutions' owners when developing new products. We also foresee those recommendations to be used by water utilities to dictate security requirements for digital solutions' owners. While developed within DWC, most of the recommendations can be extended to other critical infrastructures.
R&D	The **European Strategy for Data and associated regulations** (e.g., the Data Governance Act and the proposed Data Act) will result in significant	Stimulate to R&D funding targeted towards practical implementations of mechanisms that will contribute to systematically investigate positive and

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Type	Gap	Recommendation
	changes as to how data sharing will be performed in Europe in the years to come. The measures and objectives stated in the overall strategy and regulations will have implications the water management sector with respect to investments in ICT infrastructure, definition and use of proper governance models, data valorisation, security, trust management, to name a few. In parallel with these policy initiatives from EU, practical implementations of supporting mechanisms are emerging, such as Gaia-X and International Data Spaces. Furthermore, initiatives implemented and tested in DWC, such as FIWARE, Smart Data Models, and ETSI SAREF can make important contributions to interoperability in this setting. More research in the sense of implementation and evaluation of these political and technological concepts is needed to investigate practical implications of the EU strategy and regulations and how the policy instruments and the other mentioned initiatives together contribute to a more digitalised and innovative water management sector.	negative effects of measures and objectives of the European Strategy for Data and associated regulations. For example, practical implementations of Common European Data Spaces for data sharing involving water management stakeholders at different levels can contribute to infer barriers and opportunities of EU-policy driven data sharing and verify the suitability of the proposed measures and objectives as well as their effects.

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Overview of DWC solutions

The following table indicates the demo sites for each solution as well as the type of commercial protection selected.

Table 1: Overview of digital solutions by city and type of protection

Digital solution	Nr	Paris	Milan	Berlin	Copen.	Sofia	Type of protection
Sensors for real-time in-situ E.coli and enterococci measurements	1						Patent
Machine-learning based Early Warning System for bathing water quality	2						Open source
Early Warning System for safe water reuse	3						No protection
WebGIS platform for improved decision making in water reuse	4						Open access
Active unmanned aerial vehicle for analysis of irrigation efficiency	5.1						No protection
Match making tool between water demand for irrigation and safe water availability	5.2						No protection
Serious game for the water reuse – carbon – energy – food – climatic nexus	6						Open source
Mobile application for data collection of drinking water wells	7.1						Potentially copyright
Forecasting tool for strategic planning and maintenance	7.2						Open source
DTS sensor for tracking illicit sewer connections	8						No protection
Sensors and smart analytics for tracking illicit sewer connections hotspots	9						Patent
Augmented Reality (AR) mobile application for groundwater visualization	10						No protection
Sewer flow forecast toolbox	11						Embedded in licensed software
Interoperable DSS and real-time control algorithms for stormwater management	12						Embedded in licensed software
Web platform for integrated sewer and WWTP control	13						Embedded in licensed software
Low-cost temperature sensors for real-time CSO and flooding monitoring	14						Industrial design, trade secret
Smart sewer cleaning system with HD camera and wireless communication	15						Patent

This table summarizes for each solution: 1) the challenges addressed, 2) the technical solution, 3) the benefits obtained from the local demonstration, 4) the innovation beyond state of the art and 5) the foreseen impacts beyond the project.

Sensors for real-time in-situ E.coli and enterococci measurements	1
IPR holder: FLUIDION Main contact: Dan Angelescu (FLUIDION) TRL improvement: 6 to 8 TRL for enzymatic measurement: 4	
Challenge addressed A major challenge for urban bathing water management is ensuring the safety of swimmers. Concentrations of fecal bacteria might vary over time, as discharges from sewer overflows during intense rain events may contain high amounts of fecal bacteria and contaminate the bathing water. Traditional practices rely on the regular collection of water samples which are sent to the lab for analysis. Results are available only two days later, which is too late for reporting on the water quality or warning about pollution.	
Description The ALERT System is a 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.	

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Benefits and added value

The solution has been tested in 2019, 2020 and 2021 in Berlin, Paris and Milan. It has been validated as accurate and precise bacterial measurement systems with similar uncertainty as standard certified laboratory measurements (standard deviation of 0.03-0.15 log10 E. coli concentration). The ALERT system allows faster measurements than traditional sampling with a response time of 2 to 12 hours depending on the measured concentration.

Innovation

The innovation of the solution consists in the possibility to perform measurements on E.coli and Enterococchi concentration halfing the response times and minimising handling and transportation. It is suitable for in situ installation both in surface water and in wastewater and it's remotely controlled. A protocol for carrying out enzymatic measurements in the laboratory has been developed to reduce the time to result and pave the way for integration with the ALERT technology in a hybrid system (currently TRL 4).

Impacts

Alert system allows to increase monitoring at critical or strategic points, with fast responses and without overloading labs. Bathing site and reclamation facility managers can use it to improve their monitoring and to implement early warning systems. For wastewater utilities that plan to use such solutions to manage their effluent quality and treatment processes, having rapid feedback is essential to maintain a closed-loop feedback. Finally, drinking water utilities can benefit from such early warning in order to alert on presence of high peaks of bacteria at drinking water intakes (in which case a reserve water reservoir could be used temporarily), or could receive rapid automated alerts about presence of E.coli in the drinking water network, which could result in no-use advisories.

Machine-learning based Early Warning System for bathing water quality	2

IPR holder: KWB

Main contact: Wolfgang Seis (KWB)

TRL improvement: 5 to 6

Challenge addressed

Since the implementation of the current Bathing Water Directive (BWD) in 2006, bathing site managers are required to regularly conduct a microbiological monitoring of the water quality.

Moreover, the BWD demands authorities implement suitable risk reduction measures including early warning systems (EWS) when short-term pollution episodes are suspected. Data-driven models have been shown to increase microbial safety at recreational waters by predicting short-term pollution episodes. Besides data quality and quantity, one of the major barriers towards a wider implementation of data-driven models for improved bathing water quality management, is the complexity and required programming skills for training

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and real time implementation of such models. Currently, the European Commission is conducting a review of the BWD, which is expected to result in an increased stringency of its requirements from 2023 onwards and a push towards real time and predictive solutions.
Description SWIM:AI is a modeling platform, which allows users to develop and implement ML based early warning systems. It provides uses with a convenient user interface to configure and evaluate ML models, and proves the opportunity to use the trained model for real time predictions. SWIM:AI predicts the bacteria concentration in specific river sections. SWIM:AI processes a range of local data such as precipitation, flow, or temperature. The application is open-source and uses the reference architecture FIWARE for real time data transfer. SWIM:AI shows full complementarity with the ALERT sensors (solution 1) providing a full digital service from data collection to decision support for bathing sites. In DWC, ML models have been trained based on input data provided both local measurements and predictions generated by a deterministic model.
Benefits and added value The modeling platform SWIM:AI enables stakeholders to train ML models and use them for daily bathing water quality predictions. Thereby, it addresses one of the major barriers of bathing water quality management, namely that current analytical methods are not suitable to timely inform bathers about impaired water quality. The user friendly interface tackles a second major barrier namely that training and deploying ML models becomes much easier to develop and implement. Results showed a good agreement between the deterministic model ProSe and the machine learning approach ($R2 > 0.75$). In case of lack of quality data, the ProSe model can create it and then thanks to SWIM:AI, local health authorities can simulate the hygienic quality of bathing waters on a daily basis and thus warn of pollution and health risks in due time and avoid the risks of exposing bathers to pollution events.
Innovation SWIM:AI provides predictions on bathing water quality, using statistical methods that can be more easily implemented for an early warning, in respect to more complex models. It can also be implemented with a user-friendly interface to be used for information and communication with public, other than with monitoring and control systems. In the Paris case, two separated apps have been developed: one to communicate with the stakeholders on other parameters than the prediction and the other to inform the public on the status of the bathing site of their choice with additional practical information.
Impacts Bathing site managers can use SWIM:AI as an EWS to predict water quality and make decisions about authorizing or forbidding the bathings, according to the Bathing Water

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Directive. People can interrogate the public app to know the quality status of a bathing site and be informed on health-related risks.	
Early Warning System for safe water reuse	3
IPR holder: UNIVPM Main contact: Francesco Fatone (UNIVPM) TRL improvement: 5 to 7	
Challenge Reuse of treated wastewater for irrigation purposes is a measure to reduce water stress and overexploitation of freshwater resources. The new EU Regulation 2020/741 lays down minimum requirements for water quality and monitoring, as well as provisions for risk management, for the safe use of reclaimed water for agriculture irrigation. When the EU regulation 2020/741 will be operative at national level, the elaboration of a risk management plan will be mandatory to perform water reuse. In this context, the implementation of a digital system able to assist operators of water reclamation facilities to monitor hazards and contamination events using an automatized and continuous monitoring system may result highly strategic to minimize risks. Hence, the work conducted in DWC aimed to test the possibility to combine risk management with digitalization by the development of a Early Warning System (EWS) based on the integration of sensors measurements and machine learning algorithms.	
Description The early warning system 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 1) a comprehensive network of multi-parameter sensors at the wastewater treatment plant (WWTP) and 2) machine learning correlations to assess and predict contamination risk. Parameters to monitor and thresholds for warning are defined according to the outcomes of a risk assessment and to legislative requirements. It contributes to the implementation of the risk-based Sanitation Safety Plan based on the WHO approach.	
Benefits and added value The early warning system has been fully deployed in Milan at Peschiera Borromeo WWTP. It has been integrated in the control room with the SCADA system to process real-time data and deliver dynamic risk management and decision support for risk minimization. Particularly, it is able to provide warnings and alarms if estimated concentrations for target water quality parameters do not assure compliance with water reuse standards or are related to hazard events that may determine non- tolerable risks for human health during agricultural irrigation.	
Innovation	

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The EWS developed during DWC project is a tool designed for the wastewater reuse sector that is able to identify the occurrence of a contamination/hazard event in real-time or even beforehand to improve the safeguard of public health and the environment. It consists in an integration of sensors and soft-sensors, and it has been designed considering the outcomes of a risk assessment for agricultural reuse performed for the water reclamation facility of Peschiera-Borromeo (Milan). Measurements produced by real probes and elaborated by machine learning algorithms have been integrated in the control room with the SCADA system to realize a decision support system able to assist operators to take preventive actions and to assure the safety of water reuse practices. The development of the system has been contextualized into the framework of risk assessment and management provided by the European Regulation 741/2020, and is able to identify the suitable uses of the reclaimed water, according to the quality classes defined by this legislation.
Impacts Outcomes of the project have provided a first example of methodology for the utilization of digital data for risk management in water reuse. It highlighted the importance to produce standard protocols for the collection of reliable digital data as well as the need to link the digital information to the different components of the water reuse systems in order to monitor all possible hazardous events that can occur during water reuse implementation. In this context, the proposed EWS enhances the control and monitoring procedures supporting decision making. Hence, it can contribute to increase the social acceptability to use treated water for irrigation. In DWC project, the EWS has been implemented within the borders of the reclamation plant. However, this digital control system needs to be extended to other components of the water reuse system, including the network of pipes that distributes treated water to farmers, and critical points of the sewer network that convey raw wastewater to the WWTP facility.

WebGIS platform for improved decision making in water reuse	4
IPR holder: CAP Main contact: Marco Bernardi (CAP)TRL improvement: 6 to 8	
Challenges. Reuse of treated wastewater for irrigation purposes is a measure to reduce water stress and overexploitation of freshwater resources. The new EU Regulation 2020/741 has introduced minimum requirements for water quality and monitoring along with rules on risk management for the safe use of treated water in agriculture. Hence, new digital solutions need to be tested to assist water utilities and other interested stakeholders during decision making process in water reuse	
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 accessible to	

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all users for consulting and managing the data. A new site of WebGIS has been implemented with information about quality of treated water and for the case study of Peschiera Borromeo real time data from Early Warning System have been included.	
Benefits and added value The system has been fully deployed and tested in the area of Milan. The WebGIS gathers cross-sectorial knowledge on water management, urban planning and water quality information. It supports the management of the integrated system, being able to describe real-time characteristics and quality classes of the water and the associated risk for human health.	
Innovation The WebGIS will support water utilities to manage the integrated water service, providing information about water quality in a defined geographical and socio-economic context. Real-time communication with the EWS allows the possibility to show in real-time information about the water quality class of the treated wastewater according to the EU 741/2020 Regulation, supporting strategic management.	
Impacts The integration of the WebGIS with the information coming from the monitoring network of sensors and the EWS can improve the management of wastewater treatment service, and support decision making about treatment and reuse strategies. It can also represent a strategic communication tool in the framework of risk management.	
Active unmanned aerial vehicle for analysis of irrigation efficiency	5.1
IPR holder: UNIMI-UNIVPM-CAP Main contacts: Gian Battista Bischetti (UNIMI), Adriano Mancini (UNIVPM) TRL improvement: 5 to 7	
Challenges. See solution 4 above.	
Description The solution is based on the combination of three technologies for remote detection of water stress: 1) ground sensors, 2) unmanned aerial vehicles with spectral imagery and 3) satellites. It improves the real-time knowledge on water stress in the soil-plant-atmosphere system and enables analysis of the efficiency of irrigation schemes.	
Benefits and added-value The solution has been tested in agricultural field in the area of Milan. The combined use of the three technologies provide better outcomes than classical visual assessment or even the simple use of standard ground sensors, as common practice in agriculture. Local data analysis has shown large improvement in data accuracy as well as spatial and temporal	

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resolution. Only the smart combinations of the three technologies allow to compensate for the drawbacks and limitation of single techniques.
Innovation The key innovation is the combination of three technologies for remote detection of water stress. It provides a new efficient tool to monitor water (irrigation) and nutrient (fertilizer) needs to optimize water consumption also in reuse scenarios.
Impacts The solution will be deployed further by UNIMI and UNIVPM to support precision farming. The integrated approach is the key to minimize the use of critical resources as fertilizers and water (in case of irrigated crops); this aspect is critical especially in areas subjected to drought opening new opportunities to farmers and utilities.

Match making tool between water demand for irrigation and safe water availability	5.2
IPR holder: UNIMI-UNIVPM-CAP Main contacts: Gian Battista Bischetti (UNIMI), Adriano Mancini (UNIVPM) TRL improvement: 5 to 6	
Challenges. See solution 4 above.	
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 (solution 5.1) as well as on the amount and quality of available reused water (solution 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).	
Benefits and added-value The solution allows the deployment of precision drip irrigation scenarios compared to standard border irrigation. Local model assessments in Milan have highlighted a potential of 68% of water saving, 48% of saved fertilizers and 90% reduction of CO2 emissions.	
Innovation The match-making tool is bi-directional. On one side, it provides the farmers with a tool that combines water provision, quantitative irrigation advice and safety warnings. On the other side, it communicates both the farmers' needs and the actual use of water (both in term of quantity and quality) to the WWTP managers. The innovation resides in the digitalization of the match making between utilities and farmers.	
Impacts	

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The match making tool developed and deployed by UNIMI and UNIVPM wants to foster water reuse and optimize the management of water at regional scale by the concurrent utilization of conventional and non-conventional water sources and by taking into account the real needs for soil irrigation.	
Serious game for the water reuse – carbon – energy – food – climatic nexus	6
IPR holder: UNIVPM Main contacts: Francesco Fatone, Adriano Mancini (UNIVPM) TRL improvement: 5 to 8	
Challenges. Nexus thinking is often based on large-scale data and global water-energy-carbon-food-climatic interconnections. If this approach can drive global, international and national policies, it generally fails to support local governance. Tools are lacking to facilitate the understanding of the nexus at local scale and support decision making considering the various facets of the benefits and impacts of the practice. The nexus appears too far from local problems, and decisions related to water reuse are driven by a single objective, such as the reduction of water stress.	
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 allows 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. https://www.seriousgame4dwc.eu/	
Benefits and added value The game has been tested in Italy in several settings and have proven to successfully raise the social and public awareness about the relevance of water reuse and interconnected nexus challenges. The inclusion of public awareness in corporate and regional sustainability reporting might also boost the uptake of water reuse practices and of the related digital solutions aimed at reuse management.	
Innovation Serious game allows the general public to be informed on the benefits of water reuse. The impacts of different water management strategies can be presented into simple but scientifically based results. People can have access to scientific data about carbon footprint, energy consumption, water use and food production. Different management strategies can be selected and the related results can be compared.	

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Impacts The serious game can reach a wide public, with a catching application. Water utilities can use the tool to communicate with the users. People can be informed about the consequences and the benefits of water reuse practices, increasing their awareness.	
Mobile application for data collection of drinking water wells	7.1
IPR holder: BWB, VRAGMENTS Main contacts: Alex Sperlich (BWB), Stephan Gensch (VRAGMENTS) TRL improvement: 6 to 9	
Challenges The management of drinking water abstraction assets is a complex and wide-reaching core activity of utilities. Well data consisting of static information such as design and construction as well as operational data such as current discharge rates, water levels, previous maintenance, and water quality data are typically stored in well management databases. However, paper format is still widely used in the field to record monitoring and maintenance data and these work reports are later on transferred manually to the databases. Further, technical specifications of the well or previously recorded information on well maintenance or are not fully accessible while being on the field.	
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.	
Benefits and added value The application was tested in Berlin and showed to save time and improve employee satisfaction during preliminary assessment. Electronic documentation eliminates the need for data transfer and allows for implementation of automatic plausibility checks during data entry. BWB estimated a 40% time saving previously needed for manual documentation. Further benefits are the reduction of manual errors in the database and the presence of all data in a central storage, readily available for further data processing.	
Innovation The application enables interoperability of data across various departments within utilities and across additional stakeholders, and eases data processing routines and visualization of well condition characteristics.	
Impacts This solution is now proposed by VRAGMENTS to water utilities. BWB will use further the solution to improve data management practices and allow the future developments of data-driven predictive maintenance solutions.	

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Forecasting tool for strategic planning and maintenance	7.2
IPR holder: KWB Main contacts: Michael Rustler (KWB) TRL improvement: 5 to 7	
Challenge Well rehabilitation represents a major element of annual investments and expenses to maintain service quality. Scheduling of monitoring activities is typically based on long-term practical experience of waterworks staff. Utilities are lacking methodologies to prioritize operation and maintenance and could benefit from making greater use of sensors and available data to identify prioritize wells rehabilitation at the right time and in the right location.	
Description The solution is an open source 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. It combines automated data processing and machine-learning approaches to identify well ageing and prioritize maintenance or reconstruction needs.	
Benefits and added value The solution has been tested in Berlin in cooperation with BWB. Overall, it has proven the applicability of data-driven machine learning to support well managers in predicting ageing rates and prioritizing maintenance efforts. Data processing routine has been automatized in form of an R-package. Results reveal a high prediction accuracy, compared to current methods currently in use by the financial department of BWB for wells rehabilitation planning.	
Innovation The developed model describes existing well data better than the existing generic approach and can thus improve prediction of well ageing. This solution is the first available open source tool to optimize asset management of drinking water wells.	
Impacts BWB will further implement the solution in Berlin together with KWB. KWB is interested to further develop the tool and assess the added value in term of OPEX and CAPEX reduction. Goal is to deploy the solution among water utilities and to link the asset management of wells with other infrastructures such as sewer and drinking water networks.	
DTS sensor for tracking illicit sewer connections	8
IPR holder: P4UW	

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Main contact: Remy Schilperoort (P4UW) TRL improvement: 6 to 9
Challenge Illicit connections or sanitary sewage to the storm sewer system, usually due to unintentional errors during sewer construction or rehabilitation, are a significant source of pollution for surface waters and can threaten human health in case of bathing waters. Finding these illicit connections is like looking for a needle in a haystack as illicit connections usually occur at selected points within a large sewer network and happen intermittently.
Description Distributed temperature sensing (DTS) is a technique used to detect and locate illegal connections and extraneous inflows in sewer systems. DTS makes use of fiber-optic cables installed in the sewer system that are connected to a centrally located measuring unit. Using the principle of laser light reflection, the fiber-optic cables can serve as large temperature sensors and can detect illicit connections in the form of anomalies in the temperature signal.
Benefits and added value The solution has been demonstrated in a separate sewer system in Berlin. The main advantage of the technique is its high precision: it is able to pinpoint illicit connections to their exact location in the sewer. Main drawbacks are the relatively large effort (and hence costs) associated with the technique. Costs are around 3.5 times more expensive than conventional visual inspection (e.g. manhole inspection); considering a full rental of the equipment, OPEX amounts to > 40 k€/km.
Innovation The innovative use of temperature to track illicit connections allow unmatched precision compare to other solutions on the market.
Impacts The solution is a concrete answer to tackle the issue of illicit connections in urban areas and implement fully European directive such as the Water Framework Directive and the Urban Wastewater Treatment Directive. The solution is further commercialized by P4UW. DWC partners have shown interest for new test in Paris and Milan.
Sensors and smart analytics for tracking illicit sewer connections hotspots | 9
IPR holder: BWB Main contacts: Michel Gunkel (BWB) TRL improvement: 5 to 8
Challenge. See solution 8 above
Description

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The solution makes use of two types of sensors, electrical conductivity (EC) sensors and multiparameter sensors combined with an IoT unit (KANDO's smart unit). The sensors measure the electric conductivity of the flow in the storm sewer network. Based on the continuously measured EC signal and prior knowledge on typical EC values of stormwater (~ 200 µS/cm) and sanitary sewage (> 1000 µS/cm), it is possible to differentiate between both flows and hence identify illicit connections of sanitary sewage in the upstream storm sewer system.

Benefits and added value

The solution has been demonstrated in a separate sewer system in Berlin. The solution has proven to be 10 times more efficient than conventional visual inspection (e.g. manhole inspection) to narrow down hotspots of illicit connections in the network. Respectively, monitoring costs have proven to be 2/3 less expensive than visual inspection. While DTS (solution 8) is ideal to track the exact location of illicit connections, this solution is a cost-effective technique to identify hotspots region and narrow down investigations at catchment scale.

Innovation

This solution is a smart concept to address the issue of illicit connection at city and catchment scale. It provides a methodological guideline to start solving the associated challenges.

Impacts

Same as solution 8.

Augmented Reality (AR) mobile application for groundwater visualization	10

IPR holder: VRAGMENTS, KWB

Main contacts: Stephan Gensch (VRAGMENTS)

TRL improvement: 3 to 7

Challenge

Groundwater and the drinking water extraction process are crucial but hidden components of the water cycle, and so can be difficult to assess, evaluate and communicate.

Description

The 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.

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Benefits and added value The app has been released on main Android and IOS platforms. It has proven useful to help citizens understand key questions or urban water management, i.e. where does the drinking water come from? How does the water get into the wells? How is the water cleaned during the soil passage? The groundwater app can increase the awareness of citizens to protect their drinking water resource and better understand the actions of water utility and authorities.
Impacts Research conducted in DWC has shown that the knowledge of the general public on groundwater issues is low. The AR mobile application hast the potential to increase this knowledge, enabling users to uncover groundwater flows in Berlin. Accompanied with further measures to increase awareness on groundwater flows in Berlin (e.g. incorporating groundwater in school curricula), the app provides a building block towards spurring behavioral change and a greater sensitivity towards sustainability challenges of groundwater in Berlin.

Sewer flow forecast toolbox	11
IPR holder. DHI Main contact: Sten Lindberg (DHI) TRL improvement: 7 to 9	
Challenge The integrated management of the sewer network and the wastewater treatment plant (WWTP) is crucial to minimize sewer overflow emissions, WWTP bypasses and pollutant loads emitted via the WWTP. To better control the filling and emptying of retention basins as well as treatment processes at the WWTP, forecasts of the inflow to the drainage system and the WWTP are required. However, inflow forecasts derived from simpler methods are typically highly uncertain and only have relatively short forecast times.	
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.	
Added value and benefits The short-term inflow forecasts (lead time 3 hours) can help to guide the control decisions at the WWTP and prepare for high flow conditions during rainfall. The medium-term rain	

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probability forecasts (lead times up to 36 hours) enable more flexibility for emptying the storage basins compared to the current practice. The accuracy for short-term inflow forecast could be increased by 30% compared to hydrodynamic models. The accuracy of long-term forecast compared to measured rain data was in the range of 70-80%. Overall, the ML routine provides a significant improvement in the number of wrong switches, in the order of a 90% reduction.
Innovation Most approaches for sewer modelling are based on complex and extensive hydrodynamic models. The machine learning methodology is a simplified "end-to-end" approach where all intermediate models and their related parameterizations are implicitly described by the model. The sewer flow forecast toolbox increases forecast horizons and provides more accurate predictions than the hydrodynamic approaches currently available
Impacts DWC's experience has built a strong business case for implementing ML forecasts at other WWTP in Denmark operated by BIOFOS and other utilities. More generally, the solution will facilitate the implementation of real-time control solutions and foster the integrated management of sewer and WWTP.

Interoperable DSS and real-time control algorithms for stormwater management	12
IPR holder: DHI Main contact: Sten Lindberg (DHI) TRL improvement: 6 to 8	
Challenge. See solution 11 above	
Description The 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).	
Benefits and added value The DSS has been fully implemented and tested in the catchment area Damhusåen in Copenhagen. Analysis for the reference year 2021 have shown that the real-time control solution was able to save 25% of sewer overflow volume and 20% of nitrogen emissions. Obtaining an equivalent effect through new storage volume at the WWTP would cost the utility around 75 M€ investments	
Innovation	

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The DSS provides a fully interoperable platform including WWTP and sewer system data and models.
Impacts The solution will be further used in Copenhagen to document BIOFOS' compliance to the municipality in respect to the actual discharge permit, both on annual nutrient discharge reduction and reduced bypass volumes. It will also be used to monitor the effects of the implemented control strategy continuously and in case of decreasing effects, find the cause and evaluate other necessary measures to comply with the discharge permit, such as building more retention basins or if possible make changes to control strategy implemented in the catchment after a rain event.

Web platform for integrated sewer and WWTP control	13
IPR holder: DHI Main contact: Sten Lindberg (DHI) TRL improvement: 6 to 8	
Challenge The management of the urban water infrastructure is a complex multi-stakeholder mission. In many major cities, several operators are in charge of managing different parts of the sewer network and the WWTPs. As a result, different utilities establish individual sewer management plans and control strategies but none of them has a complete overview of the total sewer and WWTP behaviour and performance. The sharing of data and decisions between stakeholders is crucial at the urban scale in order to maximise the performance of the single infrastructures and manage the networks and WWTPs in a coordinated way.	
Description The web-based tool Future City Flow (FCF) 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.	
Benefits and added value Typical users for the platform will be planners, operators and middle management of water utilities. The solution has shown so far to foster stakeholder engagement and rational decision making using on real-time data, modelling outcomes and scenario analyses. Important in this context is the goal, that all shareholders can download the processed data and integrate them in their own control strategies based on the same data sources. At the beginning of 2023, a usability test of the solution and its dashboard will be performed with several utility managers to highlight improvement and adaptation needs.	
Innovation 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-	

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time decision-making across all utilities and entities, increasing preparedness for high-flow events.
Impacts The use of this solution is expected to empower the collaboration between BIOFOS and sewer utilities in Copenhagen. More generally, the business case of DWC has illustrated the CAPEX savings achieved by implementing specific integrated control strategies between existing storage volumes in the catchment and the WWTP. Outcomes will support the future implementation of real-time control strategies in large cities.

Low-cost temperature sensors for real-time CSO and flooding monitoring	14

IPR holder: ICRA, IOTSENS Main contact: Oriol Gutierrez (ICRA) TRL improvement: 6 to 7
Challenge Combined sewer systems comprise an underground sewage collection system composed of a network of pipes and tunnels designed to collect both wastewater and rainwater surface runoff. During heavy rainfalls, the drainage capacity of the sewer pipes and the pumping station is not able to transfer all the volume of wastewater and rainwater to the treatment plants or retention tanks. In these cases, the excess of combined sewerage is discharged directly to the receiving water body in an event called a combined sewer overflow (CSO). CSOs are a major source of contaminants for receiving water bodies, including suspended solids, organic matter, nutrients, heavy metals, organic compounds and pathogenic microorganisms. CSO events can have various detrimental effects such as oxygen depletion, ammonia toxicity and hydraulic stress on aquatic organisms. Compliance with the Water Framework Directive (WFD) requires the implementation of CSO control measures and the continuous upgrade of sewer networks to avoid environmental contamination.
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.
Benefits and added value The solution has been tested in two demo sites with 22 sensors Sofia (Bulgaria) and 18 sensors in Berlin (Germany). Experiments have shown that the measurement accuracy (in term of occurrence and duration) is similar to traditional water level sensors. The solution

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provides significant CAPEX reductions around 80% for offline sensors and 65% for online sensors compared to traditional water level sensors available in the market. OPEX savings could not be precisely assessed during the project; nevertheless, it is assumed that costs would be in the same order of magnitude as traditional water level sensors.
Innovation The innovation resides in the simplicity and robustness of the method for CSO detection compared to traditional flow and water level measurements technologies.
Impacts The deployment of the solution by ICRA can foster the implementation of European directive such as the Urban Wastewater Treatment Directive. Low cost monitoring technologies are expected to increase the knowledge about sewer networks behavior during storm events. The solution can be used to plan optimal sewer strategies at city scale (better information on overflow locations and investments needs).

Smart sewer cleaning system with HD camera and wireless communication	15

IPR holder: IPEK Main contact: Martin Stümpfle (IPEK) TRL improvement: 9 to 9 (no improvement, only demo)
Challenge Wastewater contains a variety of suspended solids and organic matter. When hydraulic conditions do not assure efficient transportation, sediments can accumulate in the network and diminish the hydraulic capacity of sewer pipes. Accumulated sediments are washed off during intense rainfalls and discharged to surface waters via combined sewer overflows (CSOs) and separate stormwater outlets. The issue of sediments is generally addressed by utilities by means of reactive maintenance (sewers are cleaned after blockages occur) or regular sewer cleaning programs. This activity represents a major expense for sewer operation and maintenance, and utilities lack solutions to support planning of cost-effective programs.
Description The smart sewer cleaning system, called Xpection, is a smart combination of a high-definition (HD) camera, a sewer-cleaning nozzle and wireless communication technology.
Benefits and added value The solution exists on the market and is fully operational. It has been tested in Berlin and Sofia in 2021 and 2022. It has proven to be a helpful additional tool for the cleaning teams in both Sofia and Berlin and was particularly useful for cleaning non-curricular pipe cross sections, where no other visual technology could be applied. It was found to be a good

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assistant in finding hidden connections and manholes, in small diameters, where CCTV crawler could not be applied.
Innovation The innovation lies in the smart combination of cleaning and CCTV surveying.
Impacts The uptake of the solution is expected to improve 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.

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