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Abstract (for dissemination)	The Smart Water Grid topical roadmap will tackle the importance of the deployment and inclusion of ICT technologies for the development of infrastructures analogous to the Smart Energy Grids focusing in the key ICT elements that can be relevant for its development in Water Sector. The main outcomes are specific analyses and recommendations for policy makers and relevant water stakeholders that can foster Information and Communication Technologies (ICT) for the Smart Water Grid. This deliverable is the third one of a series of three topical roadmaps which will help in the analysis of key issues regarding the usage ICT based solutions applied to the different water sectors.
Key words	Smart Water Grid, smart water systems, Smart Water Networks, ICT

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Executive Summary

Deliverable 2.3 consists in the report of Smart Water Grid topical roadmap. The report initially provides a revision of the current technologies that can facilitate the development of the Smart Water Grid. That revision has been done following the interests identified within water management community by asking involved stakeholders during WIDEST dissemination actions and also through a survey that has been addressed to relevant stakeholders. The revision provides, from a technological point of view, how the development of ICT can help to the development of the Smart Water Grid.

From the revision of the technologies, challenges and issues regarding the development of Smart Water Grid connection have been detected and analysed. These challenges and issues can be classified into two groups: a first one linked with technologic issues and challenges; and a second one regarding the actions that each stakeholder should overcome to help the development of the Smart Water Grid. Another important point in this roadmap has been the analysis of the current dominant solutions to advice of the developments, contributions and trends from different vendors and other entities to the field of the development of the Smart Water Grid. A list, with a deep description of the considered as the most dominant and important solutions has been provided together with some of the current trends in which the research community is focusing the new development and transference.

Finally in later sections, the roadmap provides a future vision through the statement of recommendations and actions to be taken for every relevant stakeholder, linking each recommendation to the challenge or issue that it can mitigate. As an example, specific recommendations for best funding and research directions as well as recommended actions to be taken for each specific stakeholder. A five year view of the development of tools for the Smart Water Grid is also provided, targeting the specific stakeholders that should be involved in executing the mentioned actions.

To understand this document the following deliverables have to be read.

Number	Title	Description
1.1	Report with IWO definition and implementation	This report focuses on the definition and implementation of the ICT for Water Observatory (IWO). The IWO defines a methodology to collect, analyse and publish in a knowledge base resources from relevant sources of information related to ICT for Water technologies. This report includes the objectives, methodologies, functionalities and structure the IWO is going to offer and support, conforming the inputs of the literature reviews and commercial developments and technology trends analysis.
1.3	Reports containing Literature reviews 1st release	This report presents the first iteration of ICT for Water literature review, including ICT4Water cluster projects publications, conference papers, journal papers, books and books chapters, and other reports. The objective of this report is to collect all these sources, and classify

		each document taking in consideration topics and tags. This information will be uploaded to the different platforms that support the IWO when possible.
1.4	Reports containing Literature reviews 2nd release	This report presents the second iteration of ICT for Water literature review, including ICT4Water cluster projects publications, conference papers, journal papers, books and books chapters, and other reports. The objective of this report is to collect all these sources, and classify each document taking in consideration topics and tags. This information will be uploaded to the different platforms that support the IWO when possible

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1. Introduction

The objective of Work Package 2 (WP2) is to analyse the keys issues and assimilate information across three major topics: Semantic Interoperability, Smart City Connection and Smart Water Grids. Another objective is to advice about effective implementations of each of the previously noted topics focusing on the holistic approach. The expected outcomes are specific analyses and recommendations for municipalities, decision-makers and interested stakeholders with an overview of the main technical aspects that need to be considered to effectively design and implement each of the topics covered. This will contribute to identify gaps, barriers and bottlenecks on existing regulation blocking innovations and smart technologies and also to enhance the implementation, interoperability and economy.

This deliverable (D2.3: Smart Water Grid topical roadmap) is focused in exploring the new concept of Smart Water Grids and how Information and Communication Technologies (ICT) can be used to foster the development of such new infrastructures.

Current water infrastructure is aging and deteriorating. Water distribution networks are composed of a variety of pieces (e.g. pipes, pumps, valves, sinks, etc.) made of different materials (steel, concrete and even wood), and these pieces vary in age and state. This heterogeneity in the distribution network leads to an irregular performance and efficiency (which usually can be improved with a proper network management). Even more, due to the vastness of this kind of networks and its difficult access, some municipalities may not have a complete inventory of their assets, or be aware of any leaks in the systems. In these hard economic times, funding is very limited, which sets water infrastructure lower on a priority list. However, postponing maintenance on water infrastructure sometimes results in significant component failures and main breaks that can cause other damage or disruptions.

In the age of information, no one can afford to manage an infrastructure without monitoring and analysing (in a very high frequency or real-time) the data produced by the infrastructure. ICT has been the dominant technological revolution for several decades. In addition to economic and social effects, ICT also drives changes in environmental issues and add to the portfolio of potential solutions for managing and monitoring water systems. Compared to manufacturing and service sectors, adoption of ICT in infrastructure (and more concretely in water sector) is relatively slow. One factor is presumably longer replacement time scales.

The last decade has seen progress in the development of the Smart Electrical Grid (Blumsack & Fernandez, 2012) which is an interconnected network for delivering electricity from suppliers to consumers. During the development of the Smart Electrical Grid, smart electric meters and other two-way communication devices have been installed in homes and businesses to allow electric utilities to track electrical usage in real-time (USmartConsumer, 2014). This allows utilities to make continual adjustments to the system. Whether responding to a power transformer failure or trying to help shift electrical usage to off-peak time, the hope is that smart electrical grid will make power generation and delivery more efficient and resilient and less costly, while reducing total energy use.

As reported in (European Union, 2015), the Smart electricity grids and meters in the EU Member States report (European Commission, 2014) reflected on progress in the roll-out of smart metering across the EU and found a mixed picture. Finland, Italy, Sweden advanced in their roll-out plans, installing close to 45 million meters. Another thirteen Member States declared their intention to proceed with large-scale roll-out of smart meters by 2020, although they are at different stages of the process: Poland and Romania have not made an official decision on roll-out, Spain has proceeded even without the full cost-benefit analysis (CBA) and the UK has encountered serious technical problems that have significantly delayed the process[1]. In seven Member States, the CBAs proved negative or inconclusive (Belgium, Czech Republic, Germany, Latvia, Lithuania, Portugal, and Slovakia). In Germany, Latvia and Slovakia, smart metering was found to be economically justified only for particular groups of customers. These countries now expect to roll-out smart meters to around 23% of house hold consumers. Four Member States (Bulgaria, Cyprus, Hungary, and Slovenia) did not produce CBAs or roll-out plans at all.

Although, as shown in previous paragraph, enthusiasm for smart electricity metering is not uniform across the EU, a majority of Member States still intend to proceed with large-scale deployment by 2020 and the acceptance is quite good across Europe. Smart metering systems in electric infrastructures are expected to deliver an overall benefit per customer of €309 along with assumed energy savings of 3% (European Commission, 2014). The latter range from 0% in the Czech Republic to 5% in Greece and Malta. Of the countries that have completed roll-outs, Finland and Sweden have indicated energy savings of the order of 1-3%, but no data were available for Italy.

Using ICTs in water systems and applying the lessons learnt from the Smart Electric Grid could lead to a novel technological idea called the Smart Water Grid (SWG). SWGs that are analogous water infrastructures to Smart Electrical Grids. Since 'Water Innovation Alliance' in 2009 (Hinchman, Modzelewski, & Caprio, 2012), where the prominent water-related companies around the world participated in the launch of the Smart Water Grid Initiative, the term, Smart Water Grid has been used widely (D. H. Kim, Park, Choi, & Min, 2014). A Smart Water Grid would integrate sensors, controls, and analytical components to ensure that water is efficiently delivered only when and where it is needed and help to ensure the quality of that water. Due to the readiness of the Smart Electric Grid (which surpasses the SWG), some of the ideas regarding to the application of ICT on such infrastructures, can be adapted from Electricity to Water[2].

[1] http://www.telegraph.co.uk/news/earth/energy/11242115/11bn-energy-smart-meter-roll-out-suffers-fresh-delay.html

[2] http://blogs.edf.org/energyexchange/2015/03/03/what-the-water-sector-could-learn-from-the-electric-side/

The document is structured as follows: Section 1 provides an introduction to the roadmap and also introduction to the current state of the development of the Smart Water Grid and an introduction to the Water Grid Paradigm. Section 2, provides a review of the technologies for the development of Smart Water Grid regards the water management. Section 3, provides a set of challenges and issues regarding Smart Water Grid in Water Management community. Section 4, provides a revision of the current dominant solutions in the market and trends that can appear in the future. Section 5, specific recommendations are placed for each implantation/development research direction. Section 6 targets each interested group of stakeholders and recommended actions are proposed. Section 7 concludes the document summarizing the main ideas and recommendations. Section 8 summarizes the results of the Smart Water Grid roadmap is provided. Section 9 provides the references consulted during the elaboration of this document.

2. Review of the Technologies for the Development of the Smart Water Grid

Smart Water Management combines existing water management techniques with cutting-edge ICT to enable more sustainable water management. European countries (USmartConsumer, 2014) have incorporated IT in a broad range of policies governing, ranging from Water Management to electricity, transportation, and the environment (D.-H. Kim, Suh, & Park, 2015). As a next-generation Smart Water Management Systems, the Smart Water Grid has been well received around the world due to its potential to address water shortage problems and provide new tools for energy savings.

Considering Smart Water Grids (SWGs) as integrated systems is just beginning to be considered by researchers and utilities. In the literature, there are efforts to develop and analyse the components of Smart Water Grids. Part of the literature focuses on the benefits of specific technologies such as smart pumps (Section 2.3.4) Other research lines take a step further and analyse the implementation of specific smart technology systems, such as Automated Meter Reading (AMR) and Advanced Metering Infrastructure (AMI) for water infrastructure, which are two different systems for using smart water meters for residential and commercial water consumption billing (Sections 2.3.2 and 2.3.3).

The SWG is closely coupled to the development of ICT; this means that as the ICT technologies advance, SWG would incorporate the novelties which fit in this new water management paradigm. At the current moment ICT provides to SWG the following main technological components: water resources management technology that collects and stores a variety of water resources into water platforms and also integrates and manages the distribution and transportation of water. It includes an ICT-based integration management system that can support real-time monitoring for securing, transporting and utilizing of water resources. It also supports integration management and decision making regarding water information.

2.1 State of the Current Distribution Networks

Current distribution networks face many problems in regards to water balance and resources management. This is due to the current management options, as they are limited because water network structures are based on large and centralized systems. The imbalances between the supply and demand for fresh water provoke the major limitations of these systems (UN Water, 2005) and (Hoekstra, 2010). There are more limitations such as loss and/or contamination of the supply water, high energy requirements for production and transportation of the supply water, high treatment cost and/or low treatment efficiency of both supply water and waste water due to the fixed treatment processes, and lack of integration of alternative water sources (Daw, Hallett, DeWolfe, & Venner, 2012).

As exposed in (D. H. Kim et al., 2014) due to such circumstances, it is essential to build and utilize water infrastructure such as multipurpose dams or tap water facilities. However, current water management systems fail to effectively respond to changes in water demand, occasionally triggering an imbalance between demand and supply and lowering the efficiency of facility operation. Other issues involve loss of water by pipeline water leakage and excessive use of energy spent for water production and transportation. SWG is expected to have diverse effects: improving efficiency of water production and supply with real-time water management through sensor attachments, reducing costs through systematic management of facilities, and resolving the imbalance of water resources between regions.

As reported in (Preis et al., 2015), there are some real examples of water distribution networks failures that lead to major problems among the population of big cities, for example in 2009, Los Angeles, experienced a series of pipe breaks and leaks causing significant disruption, which after expert review was associated with the introduction of a regimen of water rationing (Bardet et al., 2010). However, the lack of monitoring data made this finding largely speculative. In 2010, a huge main rupture in Boston caused two million residents of the greater Boston area to lose clean drinking water, prompting a state of emergency (Preis et al., 2015). The backup water supply did not meet US Environmental Protection Agency (EPA) standards, and the lack of a real-time monitoring regimen for water quality caused a delay: data had to be collected and analysed before authorities could assure residents that the water was safe for consumption.

Conventional centralized water networks are typically based on one-directional flow. These systems generally use dams as water sources and after treatment the product water is directly distributed to all customers in the area. However, the construction of distribution elements and the transportation of water from a single source to the entire urban area are not only economically infeasible but are also prone to leakages and pipe bursts along the transportation lines (Lee, Sarp, Jeon, & Kim, 2014). Centralized distribution networks are also more exposed to failures and attacks. Leakages and pipe bursts are common failures in urban water distribution networks; when there is a major burst in the main pipeline, a complete shutdown of the water distribution process becomes imminent. The inclusion of ICT technologies to the current distributions networks plus the development of smart grid infrastructures can help to mitigate all leakage, energy and shortage problems, due to its new management and distributed capabilities.

2.2 The Water Grid Paradigm

Decentralized systems are widely accepted as being more economically feasible, less prone to accidents, and one of the most promising approaches for improving the water management in urban areas. Decentralized systems are also suitable for using alternative water sources, such as reclaimed wastewater, rain, and sea water. However, even though decentralized systems have major advantages over conventional centralized systems, they also have management limitations when water quality and quantity are considered. Also, they need the acceptance of the users, as the water cycle has been considered as one flow stream since ancient times and costumers can be resistant to use water coming from greywater sources, for example.

The Water Grid Platform (Lee et al., 2014) divides the urban macrowater grid into smaller grids in order to establish a stable decentralization plan, while installing a central management and a storage structure. Each grid is comprised of a fresh water source, a treatment structure, a fresh water reservoir, and a residential or industrial/irrigational area. In addition to the overall grid water network scheme, alternative water sources can also be integrated to the system based on their availability in each grid. Bi-directional water flow between the freshwater reservoirs and central reservoir allows the management scheme to allocate water from one water grid to the other one without disturbing the urban water cycle and causing public annoyance. Centralized storage is a unique solution to the urban water supply and demand problems, which can collect the excess of water, produced during the night, and supply it as needed to areas in an urban area during the day, even in a spiked-demand situation.

For example, although the SWG can be applied (and also interconnected) to other fields such as agriculture and industry, sometimes the main focus is put on urban areas. The urban water cycle is categorized into two components: the fresh water cycle and the reclaimed water cycle. Multiple water sources are assigned to the fresh water cycle for mainly domestic consumption; all water reclaimed from domestic consumption is designated for agricultural and industrial consumption. Therefore, the new water grid platform configuration uses as little fresh water as possible for industrial and agricultural consumption, which fulfils the zero water discharge goal.

A more specific field, included (or closely connected to) in the urban water cycle is the domestic field. The domestic water network can be divided into several grids with respect to available fresh water sources, including ground water, water from dams, direct water intake from rivers, and water from seawater desalination. Each fresh water source is then assigned to one grid in the urban area, all of which are able to operate independently from each other. Each grid has its own fresh water reservoir, which is fed by the fresh water source via a suitable treatment system. However, in contrast to conventional design aspects, these fresh water reservoirs are connected bi-directionally to one central reservoir that will be used for back-up, quality control, and the extensive management of the domestic water cycle. In this way, the central reservoir ensures a stable domestic water supply is maintained when scenarios such as high magnitude bursts, contamination, and sudden spikes in the water demand occur. It should be noted, however, that converting all current water distribution structures from one-directional to bi-directional may not be economically feasible because of the elevation differences between the centralized and fresh water reservoirs, this means that pumping stations should be used (which leads to an increase of energy usage). Therefore, the appropriate locations of central reservoirs and the number of macro water grids required must be selected with respect to pressure points and the elevation map of the urban area.

One of the main contributions of the Water Grid is the sense that water can flow in two directions, breaking the traditional one flow idea. This is an essential part of the SWG paradigm and which also needs to be under discussion and constant development by all the stakeholders that participate in Water Management community.

2.3 Towards the Smart Water Grid

Given the problems described in Section 2.1 and in order to address the future issues regarding the bi-directional water flow proposed by the Water Grid, the Smart Water Grid places critical importance on building the next generation of water resource system and infrastructure by using multiple water sources to overcome existing water resource management system's limitations (Gwon, Jung, Lee, & Choi, 2015); Smart Water Grid further emphasizes the need for the supply and information management for stable water supply through technological innovation and intelligence by combining water resource management and ICT technology to address the continually increasing water demand in the context of rapid changes to water resource environment and rapidly changing global water industry

The Smart Water Grid is a unique infrastructure for all Water Distribution Networks (including urban, domestic, industrial and agricultural) to ensure security, quantity, safety, quality and ICT-based water management solutions. In a sense, SWG will integrate an infrastructure devoted to water transportation and supply and another ICT-based infrastructure for the management. According to (Mutchek & Williams, 2014) the SWG should integrate five prime research areas:

1. Platform configuration in both water and ICT networks
2. Guarantee water resources including both natural and manufactured water
3. Intelligent control of water flow using bi-directional communication in water infrastructure
4. Better management scheme dealing with risk-minimization for assets in the water infrastructure
5. Energy efficiency in operating and maintaining water infrastructure

This proposal divides the Water Distribution Network into two systems: (i) a bi-directional water flow network, and (ii) a bi-directional information ICT network. A theoretical SWG begins at water source, where smart meters, smart valves, smart pumps, and flood sensors are installed. Water continues on through water treatment with more smart meters, valves and pumps to monitor the continuous flow during transportation. Within a city, farm or industry distribution system, there is the addition of water contamination, temperature or nutrients sensors. At the end-use locations, end use sensing devices, smart irrigation controllers, contaminant sensors, and smart meters may be used. Finally, water moves through the sewage system to wastewater treatment and final use or discharge, where the same technologies used at the beginning of the system are used too.

Using both water and ICT platforms the intelligent water grid control plays a key role in satisfying the consumer's as well as the supplier's water needs, using self-diagnosing sensors and ICT-based cooperative networks. Improved management in risk-minimization for water infrastructure energy efficiency, low energy processes combined with alternative energy sources and smart power grid management are suggested as key cost-saving methods for water production and distribution. Figure 1 depicts the TNO Urban Smart Water Grid, which comprises also agricultural and industry linkages.

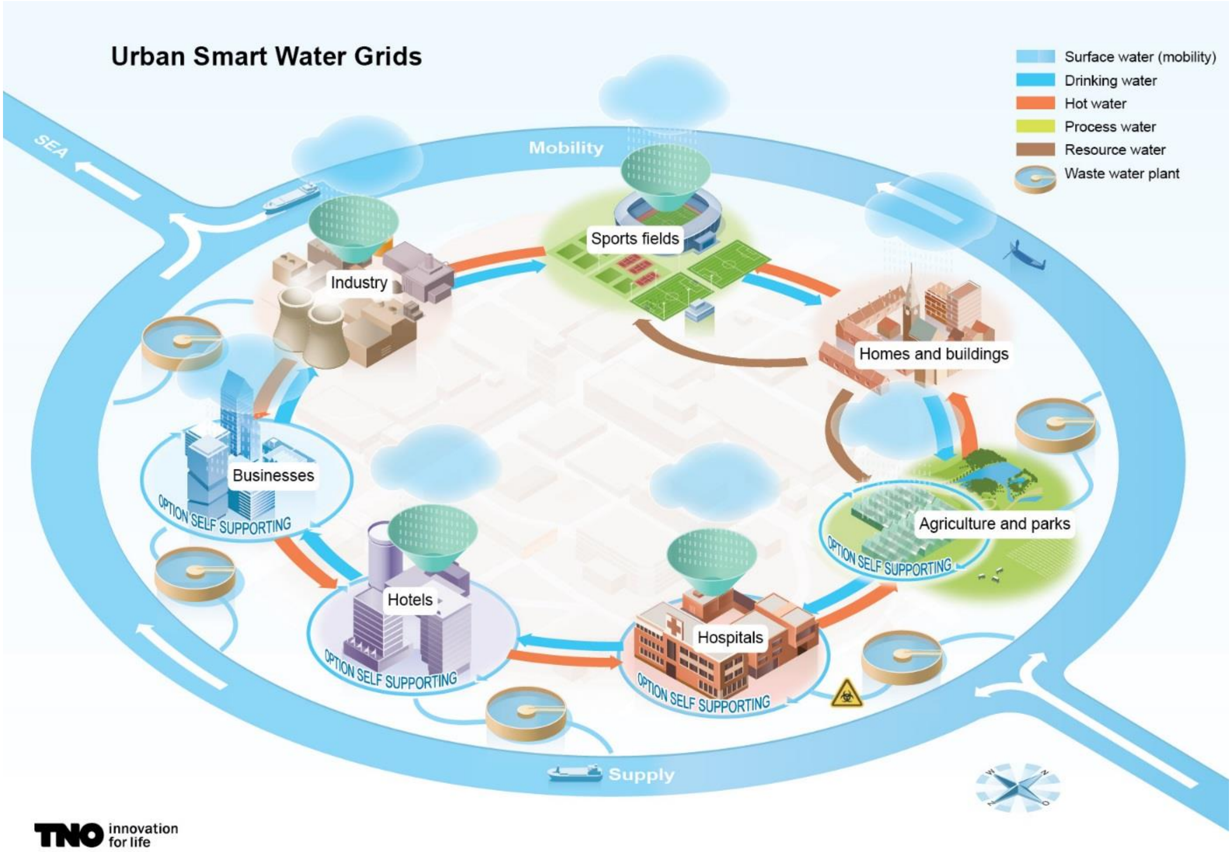

Figure 1: The TNO[3] Urban Smart Water Grid vision. Source: http://linsen.nl/tno-smart-water-grid-10-03

2.3.1 Sensing Devices

Sensing devices that collect and transmit data about the water system on a real-time basis is the foundation of any Smart Water Grid. This is one of the most relevant changes that can bring to municipalities and water utilities a lot of benefits. The traditional way of monitoring the water delivery systems has been linked to the necessity of manually read flow and pressure meters. This methodology is costly and can lead to errors, while the frequency of the readings is very low. Regarding the water quality monitoring, the traditional approach has been the recollection of water and its analysis in specialized laboratories. Again there is a high probability of errors, high costs and low frequency. In a smart water grid system, all these parameters would be collected, stored, and transmitted to a computer by the meter itself, or from a sensor to detect contamination. This increases the amount and frequency of information about the system and decreases the need for field work. Smart sensors for municipalities include smart water meters for flow, smart water meters for pressure, and contaminant sensors and biosensors for contamination detection (Pepper, Gerba, & Maier, 2009).

[3] https://www.tno.nl/nl/

Sensing Devices are suitable in many areas (residential, commercial, industrial, and agricultural). A transversal use in all areas is the single flow meter measuring total water consumption of a facility. This use is relevant as normally consumption only measured in long periods (one or two months). These long periods make difficult the detection of leakages at the needed moment and also users lack information about the water use (and precise information about systems performance regarding the use of water).

As explained in (Mutchek & Williams, 2014), an alternative to installing additional flow meters is to use a device that measure pressure waves. Each fixture has a pressure "signature" that propagates through the piping system, and a sensitive pressure-gauge can distinguish between these signatures. The HydroSense technology developed by Jon Froehlich and others needs only one sensor to determine the disaggregated use of all fixtures (e.g., faucets, toilets, and dishwashers) in a single family home (Froehlich et al., 2009). If a fixture starts to leak, the end-use sensing device will pick up this flow as "noise" in the system. For larger end-users, multiple smart meters and end-use sensing devices would be more appropriate. The key point is that a combined flow meter and pressure sensor system requires fewer devices, substantially reducing costs.

A technological addition to the water system that is useful for water storage is the flood sensor. Flood sensors detect strain on water infrastructure, such as dams, and detect early flooding over flood embankments. As an example UrbanFlood is a European project investigating the use of sensors within flood embankments to support an online early warning system, real time emergency management and routine asset management. Application of the concepts to support routine asset management, which includes the regular inspection of dikes, will also be considered. Safer dikes are not only stronger but also smarter dikes.

2.3.2 Automatic Meter Reading (AMR)

Automatic meter reading, or AMR, is the technology that permits, in an automated procedure, to collect data related with consumption, diagnostic, and status from water meter or energy metering devices (gas, electric) using sensing devices and transmit it to a central system.

This technology changes the way water provides retrieve information from users, providing economic benefits due to the lack of personnel for physically reading devices and also for the accuracy and frequency of the reads. According to this, the user can also access to its consuming data in a real-time frequency and the provider can bill the consumption accurately. Finally this fine grained information can be the root of many analyses to improve the service and also foster the savings.

Figure 2: Wireless AMR. Source: http://aggregate.tibbo.com/

AMR technologies include handheld, mobile and network technologies based on telephony platforms (wired and wireless), radio frequency (RF), or powerline transmission (Figure 2). Wireless communication has gained lot of attention due to its easiness and low infrastructure. Technologies such as 6LowPAN, LoRa, Wi-Fi, WiMAX (Section 2.3.5: Data Transmission and Power) permit to build communication flows through air without having to invest in a wired network that sometimes is impossible to build. The benefits of AMR (Khalifa, Naik, & Nayak, 2011) can be summarized as:

- Real time Pricing: Customers are charged tariffs that vary over a short period of time, hourly for example. It helps customers control their consumption and helps utility providers to better plan for the energy market.
- Automated Billing: Once the metering data is available at the utility company premises, billing, acknowledgement of received payments, and power consumption reports can be fully automated and made available to customers, on the web for example.
- Droughts management: This is another area that will be feasible after having an AMR system in place, by having current and historical consumptions, the water provider can plan a drought policy that affects less to consumers.
- Remote Connect/Disconnect: The utility provider can remotely and quickly con figure the meter to enable or disable water to certain customers.
- Outage notification: This offers an effective way to improving response time. Liu et al. [7] propose an algorithm that involves two steps: outage locating and outage confirmation through meter polling.
- Bundling with energy and gas: The ultimate objective behind a fully functional AMR is to serve all kinds of meters, electricity, water and gas, under one communication technology and one protocol standard.

2.3.3 Advanced Metering Infrastructure (AMI)

Advanced Metering Infrastructure or AMI is the new term coined to represent the networking technology of fixed network meter systems that go beyond AMR into remote utility management. The meters in an AMI system are often referred to as smart meters, since they often can use collected data based on programmed logic.

AMI has already gained some traction within the industry, with advantages suggested in the accuracy and process improvement of meter reading and control. As explained in (Backer, 2007), AMI can address the reliability, operational efficiency, and customer satisfaction with its deployment. Conversely, the benefits of AMI are countered by increases cyber security issues (Cleveland, 2008). These technologies require a communications infrastructure to provide interconnectivity. Hence, the vulnerabilities that expose other internetworking systems will ultimately lead to security threats to AMI systems.

In the Unites States, the Automatic Meter Reading Association (AMRA) endorses the National Association of Regulatory Utility Commissioners (NARUC) resolution to eliminate regulatory barriers to the broad implementation of Advanced Metering Infrastructure. The resolution, passed in February 2007, (NARUC, 2005) acknowledged the role of AMI in supporting the implementation of dynamic pricing and the resulting benefits to consumers. The resolution further identified the value of AMI in achieving significant utility operational cost savings in the areas of outage management, revenue protection and asset management. The resolution also called for AMI business case analysis to identify cost-effective deployment strategies, endorsed timely cost recovery for prudently incurred AMI expenditures and made additional recommendations on rate making and tax treatment of such investments.

Figure 3: Advanced Metering Infrastructure (AMI) Cooper Industries Vision. Source: http://www.cooperindustries.com/content/public/en/power_systems/products/automation_and_control/amr_ami.html

Advanced metering systems can provide benefits for utilities, retail providers and customers. Benefits will be recognized by the utilities with increased efficiencies, outage detection, tamper notification and reduced labour cost as a result of automating reads, connections and disconnects. Retail providers will be able to offer new innovative products in addition to customizing packages for their customers. In addition, with the meter data being readily available, more flexible billing cycles would be available to their customers instead of following the standard utility read cycles.

2.3.4 Smart Pumps and Valves

The notion of smart or smarter devices implies an introduction of intelligence to electronic devices. In that sense, smart valves and pumps apply this intelligence by adjusting their operations based on environmental conditions or signals from sensors. Apart from these automatic adjustments, as these devices are connected to a central system, they can be remotely adjusted by a human controller becoming a CPS (Cyber-Physical System). As explained in (Mutchek & Williams, 2014), variable speed pumps sense water conditions and will ramp up or down depending on those conditions. These pumps can also be equipped to sense clogs in the system and respond by breaking up clogs and/or reversing the flow. This is especially useful for wastewater and raw water conveyance. As showed in (Cruz & Grande, 2006) smart pumps can be used as part of pressure management strategies, and in (Mistry, 2005) the authors show how they can be a part of leak detection activities, or to prevent environmental contamination due to combined sewer overflows.

All these technologies can arrive at customers by means of smart irrigation controllers that can be used in water savings that is wasted on landscape irrigation. As mentioned before, applying intelligence to those smart controllers by letting them decide taking into account the weather data or sense soil moisture levels, as well as other parameters, which helps determine proper water scheduling At the end-use level, smart irrigation controllers show promise in helping to save water that is wasted on landscape irrigation. Smart irrigation controllers can receive and/or collect weather data or sense soil moisture levels, as well as other parameters, which helps determine proper water scheduling. As explained in (Southern California Area Office, 2012), by using this information, the watering schedule can be updated automatically on a daily basis. The valves and pumps that implement the actual watering of the landscape will then turn on and off at best times possible.

2.3.5 Data Transmission and Power

Once data is collected (with sensing devices or smart assets) it has to be stored or transmitted, otherwise data is lost. Local storage can be done through data-loggers attached to sensing devices, for central storage, data has to be transmitted to a central system where all data device is combined and saved. For this transmission there are two alternatives: wired communication or wireless communication. Wired communication provides most of the benefits of a reliable, secure and robust data transmission; however it is sometimes impossible to have such infrastructure due to physical or economical restrictions. Wireless transmission provides a fast and cheap alternative (depending on the technology used).

Jurisdictional and technical issues make wireless data transmission an attractive approach. Because the smart water grid is comprised of various technologies with different data transmission goals, a variety of wireless technologies and protocols are potentially useful. At the top level and as one the main protocols to use, there is the Internet Protocol (IP). It is the more extended protocol implemented in communication systems and nowadays almost any device has communication capabilities based on this protocol. On top of the IP protocol, the predominant trend of IoT delivers many possibilities such as MQTT[4] and CoAP[5] protocols. At the lower levels there are many possibilities to adapt the transmission constraints to a common interface that can be connected to an IP central network. Among these technologies there are: mobile broadband (cellular towers), wireless broadband (Wi-Fi), personal area networks (device-to-device transmission), and satellite communication. The regularity in spacing of smart water meters suggest that a mesh network design, in which each device is a communication hub for neighbouring

[4] http://mqtt.org/

[5] http://coap.technology/

devices, is a promising approach for the smart water grid (Khalifa et al., 2011). There are other RF technologies capable of transmitting data for long ranges, such as LoRa[6] (Figure 4) or Wi-MAX[7].

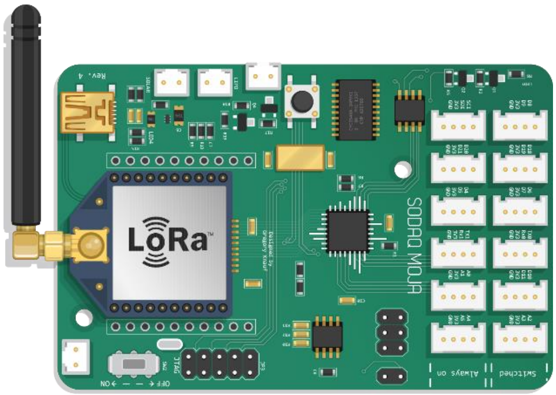

Figure 4: LoRa enabled electronic device. Source: http://www.smartliving.io/

Another issue that comes up with wired or wireless communication is the powering of devices. Direct connection to the power grid is feasible within a facility, but for devices on the water distribution system, off-grid power may be needed. This means that the power needed by the device to use a particular wireless technology/protocol will be an issue, along with the frequency of data collection and transmission by the device. Current off-grid power solutions include solar panels, water turbines, and long-life batteries (Mutchek & Williams, 2014).

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[6] https://www.lora-alliance.org/

[7] http://www.wimaxforum.org/

3. Summary and analysis of the major challenges and issues

One of the first issues faced in the adoption of the Smart Water Grid, is purely economic. The cost of the development of the SWG is high. Smart water meter systems would cost millions of euros to update, install, and maintain (Blom, Cox, & Raczka, 2010). The distribution network must be updated with the smart water meter devices (e.g., transmitters, data loggers) and pay for installation. It is considered 90 % or more of the cost of a project of this kind is in the purchase of the necessary equipment (Cheong, Choi, & Lee, 2016), such as the meters, sensors, and radio modules, as well as the information technology and data analytics solutions to effectively manage all devices and data[8]. The challenges regarding these economic problems are to really find the potential return of investment.

To drive these changes, utilities should analyse whether if they manage the transition from current networks to SWG. While self-management seems likely to minimize expense, the cost of project completion and duration may rise significantly due to a lack of dedicated and experienced expertise, impacting project quality and success. Utilities with a lack of experience in conducting a major technology transition can easily underestimate the overall impact to their organization. For example, security is a crucial issue that requires regulation and technological innovation. In order to capitalize on demand-management models, users must have easy and regular access to their consumption data. Yet access to this data has raised anxiety about the influence of such information on user behaviour. Another example is the analytical task behind the data collected, this is, once the utility or the entity in charge of recollecting the data coming from the SWG has the data in its facilities, the next step is to make this data valuable, and this task is not always easy.

Another major problem related to the adoption of the SWG is the perceived complexity of the Smart Water System and the challenges of new technology adoption. Many final users find the Smart Meter System difficult to understand and access. Water and wastewater treatment facilities avoid installing smart equipment because people consider the installation, operation, and maintenance to be more complex and risky. A good option is to provide applications that can run in customers devices, but it can also be seen an intrusion from utility or water vendor to customer's device, and thus generate resistance of such adoption.

In (D. H. Kim et al., 2014), the analysis of SWG challenges and issues is being pushed for in two dimensions: the government and the private sector (D. H. Kim et al., 2014). In the governmental dimension, the direction is toward building efficient water resource supply networks at the national level, and the private dimension concerns the construction of sensor networks for water resource and quality management and the installation of a two-way water information management system. In this document

[8] http://bv.com/Home/news/solutions/water/smart-water-technology-benefits-challenges-and-three-action-steps-for-utilities

a citizen point of view is also provided, focusing in what issues can finally arrive to final user and the challenges that the SWG may face for convincing the customers for such an adoption.

In the following subsections there is a complete list of all issues and challenges related to the adoption of the SWG.

3.1.1 Issues

This section analyses the different issues found regarding the SWG adoption at each level.

Issue	Description
Not a clear ROI on the investment of the SWG	The current Water Distribution Network requires lots of changes and investments that utilities and water providers have to face. Without incentives and a clear notion of the return of the investment, the change to SWG can be slow
Lack of funding	Adequate funding is necessary to implement SWG systems. In the current physical environment, governmental funding for water infrastructure is scarce
Low awareness among policy makers and consumers	There is low awareness about the existing water crisis among some policy makers and consumers and the imperative and urgent need to address this crisis. There is also a lack of information and understanding about the water management benefits of SWG systems and the recent advances in technology that will enable us to implement them
Lack of incentives for the adoption of the SWG	The lack of incentives for companies that can produce innovative water technology to enter and invest in this market. Technology companies would have to invest high upfront purchase while lacking an understanding of lower lifecycle costs. There is also a lack of agreement upon return on investment models by these technology providers. This problem is particularly acute for public systems that face budget constraints
Lack of interoperability among current technologies	Provide the technologies to easily make sensing devices and AMR “connectable” devices. It is not always easy to provide reading, sensing and communication at the same time due to hard access, state of the network and incompatibly among technologies. There is also the common notion of health risk of wireless communications

Issue	Description
Lack of global solutions for the SWG	The difficulty of integrated water management that incorporates the AMI service delivery, technical capability, and governance. No quick or easy solutions exist. External experts, local scientists, and people in the community can cooperate, exchange information, and ponder solutions. While the key to addressing these issues ultimately lies within the less developed nations themselves, the means for merging local, indigenous knowledge with experience from the more developed nations can be explored (Jacobs 2015). This is especially important when the SWG can manage efficiently wastewater treatment to conserve water and help increase the provision of potable water
Low awareness at citizen level	Need for raise the awareness of a change in water use behaviours: information about the pressure over the water cycle due to bad behaviours, and the cost of water by providing notions of water fingerprint
Increase the dissemination for a good acceptance of the SWG among consumers	Need for raise the awareness of a change in water use behaviours: information about the pressure over the water cycle due to bad behaviours, and the cost of water by providing notions of water fingerprint
Disseminate the potential benefits of the change of paradigm provided by the SWG	Acceptance the changes of SWG (reutilization of water): the traditional use of water should be updated to new sources and reutilization
Promote the water footprint concept among users to increase the awareness	Need for raise the awareness of a change in water use behaviours: information about the pressure over the water cycle due to bad behaviours, and the cost of water by providing notions of water fingerprint
Cybersecurity and personal data	The final costumers can see a risk in adopting these kind of solutions, as there is much personal data sent to utilities Communications at citizen level sometimes have to use Personal Area Networks or include applications in citizen’s devices. This can be seen as a drawback for the customer and block the development in the final part of the SWG

Issue	Description
Real application of the SWG among citizens	Provide useful applications and services that help to day to day life: applications and services should be focused in day to day life of citizens, if these applications and services aren't useful enough, the citizen would not use them
Assure quality of the final SWG as a product	End users request quality and reliability tests before installation. For example, intelligent metering networks would require the ability to transfer thousands of data packets per day. Transmission issues such as wireless network reliability, black spots, power source and battery life, damage by users, water proofing, and cross connections can surface and lead to questions of reliability.
Resiliency	Fear in front of communicating and power breakdowns. The service should be assured at any time by means of backup networks.

Table 1: Issues regarding Smart Water Grid

3.1.2 Challenges

This section analyses the different challenges found regarding the SWG adoption at each level.

Challenge	Description
Water Governance	"Before fixing the urban water pipes, fix the institutions". This recent quote of the OECD, highlights the relevance of water governance to improve Urban Water Cycle Services (UWCS). Water governance is the range of political, institutional and administrative rules, practices and processes (formal and informal) through which decisions are taken and implemented, stakeholders can articulate their interests and have their concerns considered, and decision makers are held accountable for water management.
City- to-city learning	The challenges require a multi-level water governance approach, a long-term strategy, a bottom-up approach and collaboration among cities and regions. Cities are encouraged to participate in learning alliances to actively share knowledge and experiences on implementation of state-of-the-art technologies (city-to-city learning). This is the most efficient way to improve UWCS.

Challenge	Description
Increase the service life of existing assets	It has to be justified that by using SWG the existing assets can extend their life by a better use or by providing efficient maintenance actions. This can be included in the ROI of the SWG.
Advice about the severe consequences of asset failure	The use of information can provide useful information about simulations of the failure of assets in specific moments
Provide remote and autonomous inspection	The autonomous inspection can benefit utilities and water providers by saving costs while improving report information
Effective use of data analysis for asset integrity management	Provide good models that guarantee the effective use of assets and provide energy savings
Decision support and decision making tools	With more data decisions can be taken in a more informative way and the use of decisions tools is one of the most challenging options
Emergency responses	Provide good information regarding current and future emergency situations. By requesting information at real-time, one can predict emergency situations and at the same time if an emergency can't be avoided, the effectiveness of the data regarded is a valuable option
Implementation of the SWG among utilities	Decision whether to manage the switch or outsource the project. While self-managing may seem like a cost-saver, a lack of dedicated and experienced resources can significantly extend project duration and impact project quality and success
Put the SWG out the urban area	Provide Smart Water Grid solutions not only for urban areas and municipalities, also for industry and farming. This idea can be linked to an enhancement of the product or service quality (pricing)
Common and standardized interfaces for interoperability among systems	Interoperability among SWG and other smart systems: with the advance of technologies, interoperability among all the products in the SWG should be guaranteed

Challenge	Description
Advance in the quality of analytic methods within the SWG	Provide useful analysis methods and capabilities for decision makers based in relevant data acquired through all the network in a very synthetic manner, that can help to understand short and long term changes within the network
Real time analysis	Real time health monitoring of critical components through continuous data reporting of assets. This data should provide a concise analysis of the current state as well as possible future failures
Energy recovery from SWG	Recovery of energy extracted from the water network.
Provide interesting citizen applications	Provide interesting services and applications that encourage the final costumer to use them. There should be a motivation (environmental. economical, etc.) that make the citizen see the SWG solutions as beneficial instead of detrimental
Securisation and anonymization	Provide policies that ensure the anonymity of data and the security of citizens using SWG services. The final user must be protected against attacks at ICT infrastructure and provide enough information about its rights regarding the use of the data retrieved so the costumer can be confident of using SWG services and applications
Promote the advantages of SWG among consumers	Make education and dissemination actions to advice about the benefits of using the SWG. As SWG implies changes in home equipment, day to day water usage and a change of paradigm in water cycle, it has to be communicated to the citizen in a proper way so they can see the benefits of changing the behaviour and adopting new technologies and habits related to water

Challenge	Description
Awareness in front of natural disasters	Provide protection to the citizen in front of disasters, such as for example severe droughts or floods. In the case of floods, information about water levels, water quality can be extremely effective to minimize the impact of the floods. In the case of extreme droughts, it can be useful to provide very efficient water schedules or forecast the water availability in order to minimize the disruptions and quality of service. Disasters quickly raise awareness, whether that be about defending against flooding or dealing with drought. Hence, adaptation measures are mainly reactive, ad hoc, and often ineffective and expensive. Globally, the main challenge is to move from reactive measures to proactive transitions, by taking bold decisions based on a cohesive long-term process
Facilitate the access to the SWG	Facilitate the access of customers to the SWG as many users find the smart meter system difficult to understand and access (Kim et al. 2014). Water and wastewater treatment facilities avoid installing smart equipment because people consider the installation, operation, and maintenance to be more complex and risky (Blom et al. 2010)

Table 2: Challenges regarding Smart Water Grid

In this section challenges and issues are revised and analysed (Table 1 and Table 2), in the next sections, recommendations to address both challenges and issues will be presented, focusing in the cutting edge technologies, dominant solutions and new research and innovation directions. When possible, specific stakeholders will be targeted to implant the innovations and one of the main goals is to provide a future view focusing in next 5 years development.

4. Summary and analysis of the dominant solutions and trends

4.1 Private Sector

Currently and according to (D. H. Kim et al., 2014), IBM in the private sector leads the development of SWG while interest from water-related businesses such as Siemens or Suez grows; IBM is globally heading the “smartisation” of the water management area by pushing ahead with development of smart water management solutions.

1. IBM is developing data platforms that can monitor, on a real-time basis, the conditions of the Hudson River (500km. length) of the US, by installing state-of-the art sensor networks covering all sections of the river.
2. In Brazil, IBM is developing geographical and spatial three-dimensional computer simulation systems that can predict the effects of utilization of land and water on the ecological system and can effectively manage the water.
3. In the Netherlands, IBM is working on a project of monitoring the condition of flood inundation, which changes moment by moment, and constructing smart levees that will respond accordingly on a real-time basis.

HydroSense also provides SWG advancements through a low-cost, single-point solution for activity sensing mediated by a home’s existing water infrastructure (Froehlich et al., 2009). HydroSense is based on continuous analysis of pressure within a home’s water infrastructure. Specifically, it identifies individual water fixtures (e.g., a particular toilet, a kitchen sink, and a particular shower) within a home according to the unique pressure waves that propagate to the sensor when valves are opened or closed. It also estimate the amount of water being used at a fixture based on the magnitude of the resulting pressure drop within the water infrastructure. The work done by Froehlich et al, represents a significant advance over prior research in several regards:

1. It can be easily installed at any accessible location within a home’s existing water infrastructure. Typical installations will be at an exterior hose bib, utility sink spigot, or water heater drain valve. If unavailable or not easily accessed (e.g., in an apartment unit), HydroSense can also be installed at the water connection point for a dishwasher, clothes washer, or toilet. All of these are simple screw-on installation points, with no need for a plumber.
2. Its analysis of pressure provides the unique capability of sensing both the individual fixture at which water is currently being used as well as an estimate of the amount of water being used. HydroSense is the first practical approach to enabling applications that require both. Its sensing of pressure is also less susceptible to ambient noise, as has been encountered in previous microphone-based infrastructure-mediated systems.
3. It has been evaluated in several diverse homes, thus providing a more robust evaluation than any previous work on water-related home activity sensing. It is demonstrated its reliable

segmentation of valve pressure events from the surrounding sensor stream, it shows reliable classification of valve open and valve close events, it shows the successful identification of individual fixtures with 97.9% aggregate accuracy, and it shows that an appropriately located and calibrated system can estimate water usage with error rates comparable to empirical studies of traditional utility-supplied water meters.

In general, it is hard to find private initiatives that provide final and complete solutions for the application of the SWG in the shape of product. In contrast all the elements present in the SWG (Section 2: Review of the Technologies for the Development of the Smart Water Grid) are distributed and commercialized separately. It can be seen as a potential barrier for the deployment of the SWG paradigm.

4.2 Public Sector

As described in public deliverable of the project BlueSCities[9]. There are some EU directives that con influence the creation of SWG in urban environments: The table below lists the main EU directives that can influence such integration:

- The Water Framework Directive 2000/60/EC creates a single system of water management, based around a natural river basin – which may form part of two or more member states, or local government areas. The directive sets objectives and deadlines for improving water quality and protecting water resources from over abstraction. It looks overall at the ecology of the water, its chemical characteristics and its quantity and flow characteristics.
- The Urban Wastewater Treatment Directive 91/271/EEC aims to protect the water environment from being damaged by urban waste water and certain industrial discharges.
- The Floods Directive 2007/60/EC requires member states to carry out flood risk assessments, create maps of flood risk and develop flood risk management plans.
- The Drinking Water Directive 98/83/EC sets quality standards for drinking water and requires drinking water quality to be monitored and reported.
- The Bathing Water Directive 2006/7/EC aims to protect public health and the environment by keeping coastal and inland bathing waters free from pollution.
- The Sewage Sludge Directive 86/278/EEC aims to encourage the use of sewage sludge in agriculture and to regulate its use in such a way as to prevent harmful effects on soil, vegetation, animals and man.

[9] http://www.bluescities.eu/

There also exist R&D EU funded projects like UrbanFlood, which is a project investigating the use of sensors within flood embankments to support an online early warning system, real time emergency management and routine asset management.

The UrbanFlood project is a EWS framework that can be used to link sensors via the Internet to predictive models and emergency warning systems. The data collected from the sensors is interpreted to assess the condition and likelihood of failure; different models will be used to predict the failure mode and subsequent potential inundation in near real time. Through the Internet, additional computer resources required by the framework are made available on demand.

A number of live pilot sites have been used to prove the methodology. Dikes are equipped with sensor systems and the EWS service built up from a series of dike failure and flooding specific modules which include dike breach evolution and flood-spreading models. UrbanFlood investigates and shows the feasibility to remotely monitor dikes and floods, whether from nearby offices or from other countries and continents through secure use of web based technologies.

5. Specific recommendations for the best funding and research directions

This section collects some specific recommendations for the best funding and research directions. Table 4 contains a set of recommendations with its description and the challenge or issue that the recommended action addresses. Challenges and issues have been identified from Section 2: Review of the Technologies for the Development of the Smart Water Grid and have been presented in Table 2.

Description	Recommendations	Challenge/issue addressed
Develop pilots for the SWG	• Establishing SWG pilot demonstrations in specific locations would help to highlight the main benefits of SWG. • This would also make visible the needs for further development and implementation of SWG systems without generating significant controversy.	• Lack of global solutions for the SWG • Not a clear ROI on the investment of the SWG • Increase the dissemination for a good acceptance of the SWG among consumers • Real application of the SWG among citizens • Assure quality of the final SWG as a product • Provide interesting citizen applications
Incentive the research around SWG	• Administrations should support and fund research and establish taxes and other incentives for SWG. • Research is needed to maximize the capability of SWG, and tax and other initiatives for utilities/municipalities, industry and consumers to accelerate their purchase and deployments of SWG.	• Increase the service life of existing assets • Advice about the severe consequences of asset failure • Provide remote and autonomous inspection • Decision support and decision making tools • Emergency responses • Implementation of the SWG among utilities • Real time analysis

Description	Recommendations	Challenge/issue addressed
	• These incentives could also come in the form of grants, loans and loan guarantees.	
Standardisation of SWG interfaces and data	• There should be agencies that incentive and develop the standards for SWG. • Establishing standards and protocols for interoperability technologies would encourage companies to begin investing in producing innovative water technology that is needed for SWG systems. • This would also incentive the market for SWG products, and make distinguish and make visible this kind of solutions. • Establish a standardization agency that fosters the development of products under the same brand name. • This would help citizens to rapidly identify a technology and recognize its benefits. These kinds of alliances have been very successful in ICT with standards such as Wi-Fi, Bluetooth, among others. If a product is branded with an standard, the customer recognizes its value and ensures the interoperability with the rest of products (that can be sold from other vendors)	• Common and standardized interfaces for interoperability among systems • Advance in the quality of analytic methods within the SWG • Securisation and anonymization • Facilitate the access to the SWG

Table 3: Specific recommendations for the best funding and research directions

6. Recommended actions to be taken for each of the targeted stakeholders to implant the innovations

A varied set of target groups and actors are considered in the context of the application of ICT for Water Management (European Commission, 2015). These include:

- Water entities, including those that treat water and/or waste-water, water supply and distribution system (WDS) operators, etc.
- Governments and other types of policy-making or influential organisations, including:
    - Municipalities
    - Water authorities/regulators (e.g., River Basin Authorities, OFWAT in the UK)
    - Environmental authorities
    - Non-Governmental Organisations (NGOs)
- Customers
    - Individual customers
    - Groups of customers (e.g., blocks of flats, suburbs, hotels, etc.)
    - Industry end-users
    - Agriculture end-users

One of the first recommendations for implanting the innovations is the coordination and synergies among these different stakeholders. It has been highlighted as one of the main challenges (European Commission, 2015) and, at the same time, opportunities in the sector. The rest of recommendations are listed in Table 4.

Recommendation	Stakeholder	Challenge/issue addressed
Provide keys in hand products for the deployment of the SWG	• Water entities	• Lack of global solutions for the SWG • Increase the service life of existing assets • Put the SWG out the urban area • Provide interesting citizen applications • Awareness in front of natural disasters • Facilitate the access to the SWG

Recommendation	Stakeholder	Challenge/issue addressed
Develop devices and applications that can be useful for customers	• Water entities • Municipalities • Water authorities/regulators • Environmental authorities • Non-Governmental Organisations (NGOs)	• Increase the dissemination for a good acceptance of the SWG among consumers • Lack of global solutions for the SWG • Low awareness at citizen level • Real application of the SWG among citizens • Put the SWG out the urban area • Provide interesting citizen applications • Awareness in front of natural disasters • Facilitate the access to the SWG
Establish governmental guidelines for SWG application	• Municipalities • Water authorities/regulators Environmental authorities • Non-Governmental Organisations (NGOs)	• Low awareness among policy makers and consumers • Water Governance • Facilitate the access to the SWG

Recommendation	Stakeholder	Challenge/issue addressed
Incentive through funded projects the application and development of SWG	• Water entities • Municipalities • Water authorities/regulators Environmental authorities • Non-Governmental Organisations (NGOs)	• Lack of funding • Lack of incentives for the adoption of the SWG • Real application of the SWG among citizens • Assure quality of the final SWG as a product • Provide remote and autonomous inspection • Decision support and decision making tools • Implementation of the SWG among utilities • Awareness in front of natural disasters • Facilitate the access to the SWG
Provide legal frameworks that stabilize the smart water governance	• Municipalities • Water authorities/regulators Environmental authorities	• Water Governance • Securisation and anonymization • Facilitate the access to the SWG
Incentive the securisation and anonimisation to protect consumer's data by current ICT security methods and create laws to assure final user security	• Water entities	• Cybersecurity and personal data • Securisation and anonymization • Facilitate the access to the SWG

Recommendation	Stakeholder	Challenge/issue addressed
Disseminate results of the current SWG applications to reach consumers and raise the awareness over current water situation	• Water entities • Municipalities • Water authorities/regulators Environmental authorities • Non-Governmental Organisations (NGOs) • Groups of customers (e.g., blocks of flats, suburbs, hotels, etc.)	• Low awareness at citizen level • Disseminate the potential benefits of the change of paradigm provided by the SWG • Promote the water footprint concept among users to increase the awareness • Real application of the SWG among citizens • Promote the advantages of SWG among consumers • Facilitate the access to the SWG
Learn from implanted pilots through the publication as Open Science the results and methods of the SWG	• Water entities • Municipalities • Water authorities/regulators Environmental authorities • Non-Governmental Organisations (NGOs) • Groups of customers (e.g., blocks of flats, suburbs, hotels, etc.)	• City- to-city learning • Disseminate the potential benefits of the change of paradigm provided by the SWG • Promote the advantages of SWG among consumers
Provide systems based on standards to assure interoperability in all levels, such as Semantic Brokers and Ontologies and Schemas for the water domain	• Water entities	• Lack of interoperability among current technologies • Common and standardized interfaces for interoperability among systems

Recommendation	Stakeholder	Challenge/issue addressed
Promote Open Data policies to incentive the sharing of data among water entities	• Water entities • Municipalities • Water authorities/regulators Environmental authorities • Non-Governmental Organisations (NGOs)	• Disseminate the potential benefits of the change of paradigm provided by the SWG • Common and standardized interfaces for interoperability among systems
Increase the analytical and forecasting tools and methods for proactive maintenance	• Water entities	• Resiliency • Advice about the severe consequences of asset failure • Increase the service life of existing assets • Effective use of data analysis for asset integrity management • Decision support and decision making tools • Advance in the quality of analytic methods within the SWG • Real time analysis
Provide a clear business plan for the application of the SWG and the applications that can issue from such deployment	• Water entities	• Not a clear ROI on the investment of the SWG • Lack of global solutions for the SWG

Table 4: Recommended actions to be taken for each of the targeted stakeholders to implant the innovations

7. Conclusions and Recommendations

Table 5 summarizes the actions to be taken within a stage of action. The stages are tied to short-term actions (to be taken within the following year), mid-term actions (to be taken within the next 2-3 years) and long-term actions (to be taken within the next 5 years). Also these actions are tied to some stakeholders, as not all recommendations should be taken for each stakeholder.

Recommendations	Stakeholder	Stage
Establish guidelines for the implantation and research	• Municipalities • Water authorities/regulators • Environmental authorities • Non-Governmental Organisations (NGOs)	Short-term
Incentive the research around SWG	• Municipalities • Water authorities/regulators • Environmental authorities	Short-term
Incentive and promote SWG R&D projects	• Water entities • Municipalities • Water authorities/regulators • Environmental authorities • Non-Governmental Organisations (NGOs)	Short-term
Develop pilots for the SWG	• Water entities • Municipalities • Water authorities/regulators • Environmental authorities • Non-Governmental Organisations (NGOs) • Groups of customers • Industry end-users • Agriculture end-users	Mid-term
Provide policies around the utilization of the SWF	• Municipalities • Water authorities/regulators • Environmental authorities	Mid-term

Recommendations	Stakeholder	Stage
Present key-in-hand products	• Water entities • Groups of customers • Industry end-users • Agriculture end-users	Mid-term
Link with Smart City	• Water entities • Municipalities • Water authorities/regulators • Environmental authorities • Non-Governmental Organisations (NGOs) • Individual customers • Groups of customers • Industry end-users • Agriculture end-users	Mid-term
Provide semantic connection to other Smart City systems	• Water entities • Municipalities	Long-term
Provide products on top the SWG infrastructure	• Water entities	Long-term

Table 5: Recommendations to be taken in the future

8. General summary

The current Deliverable is the Smart Water Grid topical roadmap which intention is to analyse the current state of the technologies that can permit the development of the Smart Water Grid infrastructure and also identify the barriers and challenges of the adoption of such technologies and provide a vision for the future while providing relevant recommendations for involved stakeholders in the field.

To analyse the barriers present in the adoption of such technologies this document first provide a revision of the technologies that can facilitate this development. This revision has been done by targeting the most promising technologies by querying both the current literature and also the involved stakeholders through personal informal meetings and a specific survey distributed by electronic mail. The results of this revision can be found in Section 2.

Later, in Section 3 an analysis of the main challenges and issues identified during the revision of the technologies (Section 2) is provided. These challenges and issues can be divided into two groups: a first group which is focused in technological barriers and challenges regarding the development and adoption of the Smart Water Grid; and a second group of regulatory/educational challenges and issues that all stakeholders can contribute to overcome. These challenges and issues have been used later in the document to identify possible actions and recommendations for the future.

In Section 4, an analysis of the main solutions present in Water Management community is provided. Included in this analysis there exist public initiatives that can foster the development of smart water systems and Smart Water Grid, but also private initiatives. After the analysis it has been found that not many keys-in-hand products exist in the market. This confirms the potential gap in this market and the interest of the ICT companies. Also the trends that will help to cope with the barriers have been identified, especially these technologic trends/ideas that deserve a special attention in near future.

The rest of the roadmap is devoted to the identification of actions to be taken in the future. Section 5 targets some of the best research directions to be funded, which can help in the development of the Smart Water Grid for Water Management community. Later in Section 6 recommended actions for each stakeholder are provided, these recommendations are linked to the challenges and issues that each action helps to solve while each stakeholder that is involved in the execution of the action is also identified. The roadmap concludes in Section 7 providing a 5 year vision of the actions to be taken in the future for each stakeholder.

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