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Espinosa Apráez, Brenda

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# Digitalisation in the drinking water sector

Brenda Espinosa Apráez[1], Tilburg Law and Economics Center (TILEC) – Department of Law, Technology, Markets and Society (LTMS), Tilburg University, the Netherlands

## 1. Introduction

Water supply is one of the most critical network industries, given its direct link with basic human needs. As recognized by the General Assembly of the United Nations (UN) in 2010, the right to safe and clean drinking water (and sanitation) is "a human right that is essential for the full enjoyment of life and all human rights" (United Nations, 2010 Article 1). According to the Committee on Economic, Social and Cultural Rights of the UN, there are three basic factors that underlie the right to water that states should guarantee: availability, quality and accessibility (CESCR, 2002). *Availability* refers to the sufficient and continuous supply of water for personal and domestic uses. *Quality* entails that water should be "free from micro-organisms, chemical substances and radiological hazards that constitute a threat to a person's health", and should be "of an acceptable colour, odour and taste for each personal or domestic use" (CESCR, 2002, p. 5). *Accessibility* means that water services should be accessible to everyone in four dimensions: physical accessibility, economic accessibility (affordability), non-discriminatory access, and information accessibility.

Due to the chief importance of water services, ensuring availability and sustainable management of water and sanitation is one of the goals (the number 6) in the UN 2030 Agenda for Sustainable Development (United Nations, 2015). Achieving this goal does not come without challenges, as there are certain contextual factors that increasingly compromise the availability, quality and accessibility of water. First, the steady growth in global population and extreme weather conditions as a result of climate change, are raising concerns regarding water scarcity (Boyle et al., 2013, p. 1053; Lloyd Owen, 2018 Ch. 2). In addition, water infrastructures are ageing and will require rehabilitation or replacement in the coming decades. According to estimations included in a report published by K-water (2018, p. 428) approximately €20 billion per year will be necessary to keep distribution networks in Europe in good condition, calling for prioritization and optimization of investments in the sector. Moreover, pollution of ground and surface water sources as a result of industrial and agricultural activities and inadequate sanitation are worsening the quality of water for human consumption (see Singh, 2016, p. 4; United Nations, 2018, p. 141). Climate change has also a negative impact on water quality, due to higher water temperatures and the pollution risks associated to flooding and drought (UNESCO World Water Assessment Programme, 2020, p. 1).

The provision of drinking water is carried out by public or private organisations known as 'water utilities', which are in charge of abstracting, treating and distributing water for human consumption, and managing the infrastructures therein involved. The need to obtain more precise and timely information to tackle the abovementioned challenges has motivated water utilities to embrace digitalisation. This has been facilitated by the fact that advanced sensing tools and

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[1] PhD researcher affiliated to TILEC and LTMS at the Tilburg University's Law School in the Netherlands. E-mail address: b.p.espinosaapraez@tilburguniversity.edu.

computing capabilities are increasingly available at a cost that, conversely, tends to decrease (Eggimann et al., 2017, p. 5; Lloyd Owen, 2018, p. 76; Nguyen et al., 2018, p. 257).

This contribution outlines key aspects of the growing digitalisation of the drinking water sector and discusses how this approach is changing the management of the infrastructures therein involved. Furthermore, it explores the challenges and the roles of regulation and policy in this transformation. To this end, several sources were surveyed, including academic and non-academic literature, regulations and policy reports.

The remainder of this chapter is organized as follows: Part 2 provides an overview of the technologies behind the digitalisation of the drinking water sector. Part 3 discusses the impact of digitalisation on the management of drinking water infrastructures and other aspects of drinking water supply. Part 4 is dedicated to exploring possible changes in market structure in the sector under study as a result of digitalisation. Part 5 refers to the challenges brought about by digitalisation, in particular the ones relevant from a policy perspective. Part 6 discusses the role of regulation and other policies in the path toward digitalisation of the drinking water sector. The conclusions of this chapter are presented in Part 7.

## 2. The technologies behind digitalisation in the drinking water sector

The term *smart water management* is commonly used to encapsulate the digitalisation of the drinking water sector (see e.g. K-water, 2018; Lloyd Owen, 2018). Therefore, this expression will be used interchangeably with digitalisation in the remainder of this chapter. Smart water management is understood as the use or integration of Information Communication Technologies (ICT) in water management (Choi et al., 2016, p. 2; International Telecommunication Union, 2014, p. 4; K-water, 2018, p. 25). A noted by a report from the International Telecommunication Union (ITU), smart water management encompasses an array of technologies that allow for data acquisition and integration, modelling and analytics, data dissemination, data processing and storage, management and control and visualization and decision support (International Telecommunication Union, 2014, p. 4).

In its 2014 report, ITU classifies smart water management tools in six main categories, with possible overlapping areas. These categories are shown in Table 1.

*Table 1. Types of smart water management tools (**source:** the author, based on International Telecommunication Union (2014, p. 4)*

| **Category** | **Examples** |
|---|---|
| Data acquisition and integration | Sensor networks, smart pipes, smart meters |
| Modelling and analytics | ‘MikeURBAN’ |
| Data dissemination | Radio transmitters, WIFI, Internet |
| Data processing and storage | Cloud computing |
| Management and control | SCADA, optimization tools |
| Visualization and decision support | Web-based communication tools |

It goes beyond the scope of this contribution to provide a detailed description of all the technologies used for smart water management, but the most commonly cited examples will be briefly outlined.

### a. Smart water metering

When thinking of digitalisation in the drinking water sector, the first example that comes to mind are smart water meters. This is not surprising because, as noted by Lloyd Owen, they are the technology that people (consumers of drinking water) are most likely to encounter (Lloyd Owen, 2018, p. 86). Smart meters are not only used in the water sector. In fact, their use is more widespread in the energy sector (electricity and gas). In Europe, this is due largely to the existence of European Union (EU) legislation that mandates the roll-out of smart meters in the energy sector. [2] In contrast, there are no EU-wide policies that explicitly encourage a broad adoption of smart meters by water utilities.

Although there is no agreed definition for this type of technology, in general terms, smart meters are "a component of the smart grid that allows a utility to obtain meter readings on demand (daily, hourly or more frequently) without the need of manual meter readers to transmit information" (Arniella, 2017, p. 15). Smart water meters differ greatly from so-called 'dumb' (mechanical accumulation) meters. While the latter require manual readings taken usually once or twice per year, smart water meters allow for more frequent, higher resolution and remotely accessible (consumption) data (Boyle et al., 2013; March et al., 2017, p. 2).

The possibilities enabled by smart water meters are summarized by Espinosa Apráez and Lavrijssen (2018, p. 162) as follows:

- *precise consumption measurement, reducing billing errors and disputes with consumers;*
- *monitoring the water system in a timely manner;*
- *easing and lowering the cost of meter reading (avoiding manual reading);*
- *providing precise data to balance water demand;*
- *facilitating prompt leak detection in consumer premises or other parts of the network (e.g. analyzing information generated from a building or a block);*
- *prompt detection of theft or other causes of water loss;*
- *creating awareness about water conservation and facilitating enforcement of local water restrictions;*
- *applying dynamic prices; and*
- *additional features may also enable to measure water quality parameters, such as temperature or pressure.*

The literature usually distinguishes between two types of smart meters: (1) automated meter reading (AMR), and (2) automated or advanced metering infrastructure (AMI) (see e.g. Arniella, 2017; Boyle et al., 2013; Lloyd Owen, 2018). AMR was the first approach to make water meters smarter. Mechanical ('dumb') meters were "complemented with a system with datalogger and communication equipment, which allows readings to be taken using portable equipment (*walk-by*) or using vehicles (*drive-by*) which circulate through the streets of a city, scanning the nearby meters" (Sempere-Payá et al., 2013, pp. 248–249). AMI goes one step further and allows for two-way communication between the meter and the utility, making possible that the meter readings are directly sent to the utility (Arniella, 2017, p. 15; Sempere-Payá et al., 2013, p. 249). Some authors report that only AMI can be truly considered smart metering, to the extent that what makes metering 'smart' is the connection of the meter to the communication network (Boyle et al., 2013; Lloyd Owen, 2018). Other authors consider as true smart metering only the evolved versions of AMI,

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[2] For the electricity sector, this was first introduced by Directive 2009/72/ EC of The European Parliament and of The Council of 13 July 2009 (Annex 1, paragraph 2). The 2009 Directive was recast in 2019 by Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU. The provisions concerning the deployment of smart metering can be found mainly in Article 19-21 and Annex II.

which allow for real time communication using private communication networks combined with a new generation of meters, so-called interval water meters (Sempere-Payá et al., 2013, p. 249).

### b. Sensor networks

As mentioned in the Introduction of this chapter, guaranteeing the quality of drinking water is a paramount obligation of states and water utilities. Drinking water quality is assessed against certain standards related e.g. to microbiological, chemical and organoleptic parameters. Globally, the best-known standards are the Guidelines prepared by the World Health Organization.[3] In the European Union, the drinking quality standards are set by Council Directive 98/83 /EC on the quality of water intended for human consumption,[4] known as the *Drinking Water Directive*. The monitoring of water quality has been traditionally carried out by collecting samples at given points of the network with a certain periodicity, which are then analysed in a laboratory to assess whether they meet the relevant standards. This approach has its limitations: it does not allow for real-time monitoring of the quality of water (i.e., there is a time gap between sampling and detection of contamination), the samples are taken at a small number of locations and it is labour-intensive (Lambrou et al., 2014, p. 2765).

Sensor networks can contribute to mitigate these limitations. They entail the installation of different types of wireless sensors inside the water pipes, to measure in real-time parameters such as temperature, conductivity, pH, pressure, turbidity, dissolved oxygen, etc (Carminati et al., 2020; Lambrou et al., 2014). The data collected with these sensors is sent to the utility which then can take prompt action if there is a threat of contamination. The data can also be used to create models to predict changes in the water quality and/or the need of pipe maintenance, and to optimise water treatment processes (Carminati et al., 2020, p. 4).

### c. District metered areas (DMAs)

DMAs are a method of measuring water loss that consists in dividing the water distribution network in several subsystems, where water supply and consumption are measured individually from the rest of the system (Arniella, 2017, p. 18). They are a combination of several tools (hardware and software), including (smart) water meters, geographical information systems, different types of sensors (pressure, temperature, etc.), hydraulic models and algorithms.

DMAs can be used to identify deviations from normal flows and pressures, and as such, they enhance pressure management and pinpointing of leakages along the distribution network (Arniella, 2017, p. 20). Some reports refer to further subdivisions within DMAs, (SDMAs), which, with the help of smart meter data, can help to find leakage points, not only in the distribution network but also at the home of the consumer (K-water, 2018, p. 93).

### d. Modelling

Developing models and algorithms based on the data collected with smart meters and other sensing technologies can help water utilities in several fronts. For example, hydraulic modelling can be used for pipe network analysis, which are useful to plan future infrastructure expansion and validate

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[3] The latest (and fourth) edition of the Guidelines for Drinking Water Quality (GDWQ) was officially adopted in 2011, but there is a version published in 2017 that incorporates an addendum to the fourth edition (World Health Organization, 2017)

[4] Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption, OJ L 330, p. 32-54.

the design of new or rehabilitated pipelines (Arniella, 2017, p. 28). Modelling can be also used to predict changes in water quality in the distribution network, caused by different factors (chemical or biological, loss of system integrity, etc.) (Arniella, 2017, p. 29). Another use of modelling in the management of drinking water infrastructure is forecasting water demand, which often times is a difficult task considering that water demand is subject to daily, weekly and seasonal variations, and in addition is affected by external factors (e.g. socioeconomic and meteorological) (Romano & Kapelan, 2014, p. 265).

### e. Supervisory Control and Data Acquisition (SCADA)

SCADA is a technology that enables the remote monitoring of a system or parts of it and, by means of processing information, it can generate reports or alarms useful for operation and maintenance (Temido et al., 2014, p. 1631). In the management of water systems, and with the help of sensors and other data-collecting devices, SCADA can monitor and control various assets and processes from source to tap (Arniella, 2017, p. 27; Temido et al., 2014, p. 1634).

The previous paragraphs provided a brief description of some of the most common technologies used for smart water management in the drinking water sector. The list was far from exhaustive, since there are many other technologies such as geographic information systems or visualisation technologies (e.g. digital twins) that have been and continue to be developed. All these technologies have in common that they allow for obtaining improved data about the condition and functioning of infrastructures and the quality of the drinking water. Having more accurate and (near-to) real time data allows infrastructure managers to perform better assessments of the present situation, minimising service disruptions and damages to the infrastructures, as well as predicting and preparing for future scenarios.

## 3. The impact of digitalisation in the drinking water sector

Specific figures that reflect cost savings or efficiency increase as a consequence of digitalisation in the drinking water sector are scarce and scattered in academic literature. In a 2017 literature review of data-driven urban water management, Eggiman *et al* note that “clear evidence for a beneficial cost-benefit ratio that would justify widespread implementation of a more data-driven [urban water management] is generally missing” (Eggimann et al., 2017, p. 33). However, in ‘grey literature’ such as industry reports or handbooks it is possible to find references to successful case studies (see e.g. K-water, 2018; Lloyd Owen, 2018).

This lack of substantial evidence in academic literature is explained by different factors. Firstly, it might be too soon to evaluate the actual impact of digitalisation on the management of drinking water infrastructure. On the one hand, some sources note that even if digitalisation is growing the water sector, the level of maturity “concerning the integration and standardization of ICT solutions, their business processes and the related implementation in the legislative framework” is still low (Anzaldi Varas & ICT4Water, 2018, p. 34). Moreover, the degree of openness to innovation is lower in this sector, compared to energy or telecoms (Lloyd Owen, 2018, p. 58). On the other hand, the benefits of smart water management usually become visible after several years and many projects are still ongoing or were recently completed. For example, in a case study of smart water management in the city of Seosan (South Korea), a smart metering program was put in place in June 2016 and projections indicate that net benefits will become visible after about four years (K-water, 2018, p. 102). Another factor that explains the absence of clear figures regarding the impact of digitalization in the sector under study, is that the benefits of more data are difficult to foresee and improvements such as greater flexibility are hard to measure (Eggimann et al., 2017, p. 30).

Even if more evidence of the specific impact of adopting smart water management technologies has yet to come, there are already sources that report on the potential of digitalization to transform and improve the management of drinking water infrastructures and drinking water supply, as it will be shown in the following paragraphs.

### a. Impact on design of infrastructures

Improved water consumption data, obtained primarily with smart water meters, can help utilities to design and plan the upgrading of their infrastructures in a way that reflects the actual needs of the system. Daily demand profiles and peaking factors (e.g. peak hour and peak day) are necessary information to plan and design infrastructures such as pumps, pipes and storage reservoirs (Gurung et al., 2014, p. 34; Nguyen et al., 2018, p. 258). While traditional methods to obtain such variables usually rely on assumptions and outdated information resulting in infrastructure that is overdesigned, smart water metering allows for high resolution and up-to-date data that can be used to model water demand more accurately (Gurung et al., 2014, p. 34). For example, in a study carried out by Gurung et al (2014), the peak day consumption modelled using smart meter data was 12% lower than the one assumed by the water utility.

More accurate information about the actual needs of the system prevents that infrastructures are unnecessarily overdesigned and allows to avoid or delay upgrading or expanding the infrastructure, if the full capacity has not been reached yet.

### b. Impact on the monitoring and maintenance of infrastructures

Digitalisation has also the potential of transforming the maintenance of the drinking water infrastructures. Water utilities face an important challenge, considering that a large part of their assets is located underground, making the monitoring more difficult and expensive. Adopting smart water management approaches can help drinking water utilities to tackle that challenge in a number of ways. For example, the use of smart water metering and (sub)DMAs helps to pinpoint leakages in the water mains and also at the home of the customer (see Part 2, section b of this chapter). Remote acoustic sensing is another technique that helps detecting leaks avoiding manual inspections which are more labour-intensive and usually less timely (Lloyd Owen, 2018, p. 130). With the use of the referred technologies, water utilities can find and address the leakages faster, reducing service disruptions and non-revenue water (i.e., water that is put into the water network but does not reach the customer and thus is not billed, (Rudolf Frauendorfer & Roland Liemberger, 2010, p. 5)).

Smart water management techniques can also help infrastructure managers in determining more accurately when their assets require maintenance or replacement. In traditional approaches, infrastructures are managed following assumed operating lifetimes, rather than on the basis of their actual condition (Lloyd Owen, 2018, p. 50). The advent of digitalisation and more data-driven approaches have made possible the development of models that allow to predict failures in the water infrastructures, such as pipe deterioration (Z. Li & Wang, 2018; Winkler et al., 2018). This opens the door to abandon corrective or preventive maintenance methods and move toward more condition-based or even predictive maintenance approaches.

In sum, digitalisation allows for better monitoring and timelier (not-too-soon, not-too-late) maintenance of drinking water infrastructures. As a result, major disruptions can be prevented and investments in rehabilitation or replacement can be avoided or deferred.

### c. Impact on water demand management

*Water demand management* is an approach to managing water resources that aims to "develop and implement strategies to manage supply more efficiently, as well as enact water conservation measures and drought response plans when needed" (Nguyen et al., 2018, p. 256). Considering the increase in population and the risks of water scarcity exacerbated by climate change, water demand management policies are becoming increasingly relevant to secure sufficient availability of drinking water. Water demand management includes several aspects, such as engineering, economic and other types of incentives, enforcement and education (Nguyen et al., 2018, p. 256). Smart water technologies play an important role in making water demand management possible and effective.

For example, with the help of smart metering, water utilities can have more detailed insights on water consumption trends. This information can be also shared with the customers by means of visualization tools, in order to increase awareness and stimulate water savings, especially in peak hours or during dry periods (Temido et al., 2014, p. 1637). Smart meters are also crucial to implement dynamic pricing or time-of-use tariffs as economic incentives to implement water demand management policies. Examples of application of such incentives are imposing penalty fees for exceeding a certain threshold of water consumption especially during dry seasons, or providing periodic incentives to lower consumption during peak hour (Cole & Stewart, 2013, p. 193; Nguyen et al., 2018, p. 258).

### d. Other impacts of digitalisation

So far, this part has discussed and provided examples of the impact of digitalisation in the management of drinking water infrastructure in three main fronts: design of infrastructures, monitoring and maintenance of infrastructures, and management of water demand. However, there are other areas than can be also (positively) affected by digitalisation in the drinking water sector. For example, smart water management approaches in the contribute to save energy costs in the production and distribution of drinking water (J. Li et al., 2020, p. 14). In this respect, Lloyd Owen refers to the possibility of optimising the operation of pumps with the use of sensors that transmit pressure data and algorithms that determine in real time the required pressure within the distribution network at any given time (Lloyd Owen, 2018, p. 133). Since pumps account for the largest share of energy consumption in a water distribution system, this form of pressure management helps to use pumps more efficiently thereby contributing to save energy costs.

Digitalisation can also contribute to better monitoring of drinking water quality, as exemplified by the sensor networks discussed in Part 2, section b of this chapter. Among others, real-time monitoring water quality helps utilities to avoid over-using substances for treatment (e.g. chlorine), which improves the taste of the water and saves chemical costs (Lloyd Owen, 2018, p. 134).

Finally yet importantly, digitalisation can enhance customer service and satisfaction (International Telecommunication Union, 2014, p. 13). For instance, as discussed along this chapter, smart water technologies can help utilities to detect and react more quickly to adverse events, thereby minimising service disruption. In addition, as discussed in Part 2, section c, the use of DMAs and smart water metering allows to pinpoint internal leakages at the homes of consumers, which can be proactively notified by the utilities. Lastly, smart water metering allows for less disturbance of consumers (they do not need to be present for water meter readings or do not have to send the readings manually); and more detailed consumption information, which translates into more accurate billing and the possibility of adjusting water consumption to save in utility expenses (see J. Li et al., 2020, p. 15).

## 4. Possible changes in market structure

One of the consequences of digitalisation of network industries is the emergence of new actors in the market structure of each sector. A prominent example of these new actors are online platforms that enable coordination among different industry players, as illustrated by Montero and Finger in their analysis of platformisation in the telecommunications, transport and energy sectors (Montero & Finger, 2017). In the electricity sector, other actors have emerged as a consequence of digitalisation and decentralisation (see Lavrijssen & Carrillo Parra, 2017). A key example of this are 'prosumers' (or active customers), which were included in the recently adopted Directive (EU) 2019/944 on common rules for the internal market for electricity. Active customers are defined by the said Directive as final customers that consume, store or sell self-generated electricity and/or participate in flexibility or energy efficiency schemes, as defined in the recently adopted (Art. 2(8)). Comparable significant changes in market structure are not evidenced in the drinking water sector. This might be related to the fact that, unlike other network industries, the provision of drinking water is usually vertically integrated, i.e., the abstraction, treatment and distribution of water to consumers are carried out by one water utility. In addition, it is unlikely that there will be prosumers in the drinking water sector due to health and water quality reasons and other resource related limitations that make self-production of water much more difficult than self-production of electricity.

Even if it does not seem likely that new actors will emerge in this sector as a result of digitalisation, what is feasible is the emergence or growth of markets for services based on the increasing amount of data that water utilities collect with the help of smart technologies. As it has been explained in this contribution, thanks to digitalisation, more data on water consumption and on the functioning and condition of infrastructures become available. Such data can be used by the utilities themselves to improve their processes, but the data can also be used to develop new products or services either by the same water utilities or by other service providers.

Think for example of applications that help consumers to have better insight of their water consumption, help them to save water, or adjust their consumption to benefit from time-of-use tariffs (see Part 3, section b). Another possibility enabled by digitalisation in the drinking water sector and other sectors (e.g. energy, health and safety), is the development of smart home systems (OECD, 2017, p. 114). Following Hargreaves and Wilson, smart home technologies "comprise sensors, monitors, interfaces, appliances and devices networked together to enable automation as well as localised and remote control of the domestic environment" (Hargreaves & Wilson, 2017, p. 1). Providers of smart home solutions take advantage of the ICT embedded in home appliances (such as TVs, fridges, lighting or washing machines) and take it one step further to make the home as a whole 'smart' and to "link these smart homes into the meters, wires and pipes of the utility networks"(Hargreaves & Wilson, 2017, p. 1).

Another possible development that relies on the combination of data from water and other utilities is the advent of a so-called 'digital multi-utility service provider' (Nguyen et al., 2018, p. 265; Stewart et al., 2018, p. 96). This idea is still in an early phase of research, but it is interesting to examine it as a possible outlook of digitalisation in the drinking water sector and other utilities. Digital multi-utility service providers would "collect a customers' medium-high resolution water, electricity and gas demand data and provide user-friendly platforms to feed this information back to customers and supply/distribution utility organisations" (Nguyen et al., 2018, p. 265). With the combination of the different streams of data, the 'digital multi-utilities' can harness the water-energy nexus. The 'water-energy nexus' refers to the link between consumption of water and energy (electricity and gas). In domestic utilities consumption, this is evidenced by the use of energy for water heating (see Lloyd Owen (2018, p. 94)). The combination of data from different utilities would allow the 'digital multi-utilities' to create innovative tariff structures and tailored resource conservation products and rebates, and also manage peak demand in the different utilities, among others (Nguyen et al., 2018, p. 265; Stewart et al., 2018, p. 96).

## 5. New challenges

Digitalisation brings interesting opportunities to improve the processes involved in the provision of drinking water, but at the same time, it comes along with challenges. Some of the most relevant challenges are discussed below.

### a. Financial challenges

Even if the cost of smart water technologies tends to decrease over time, the initial investments required to fully digitalise the management of drinking water infrastructures are still rather high, compared to less 'smart' approaches. For example, deploying smart meters is more costly than traditional meters, not only because the metering devices are more expensive, but also because smart metering requires a communications infrastructure to operate (K-water, 2018, p. 99; Lloyd Owen, 2018, p. 87). Moreover, on the top of the traditional investments for construction and maintenance of physical infrastructure, smart water management approaches require investing in technologies for the collection, communication, analysis, and storage of data, which require upgrading and maintenance themselves.

The higher costs involved, together with the fact that the expected benefits are often difficult to quantify or realize in the short term (Eggimann et al., 2017, p. 30), are still factors that prevent a broader uptake of digitalisation in the drinking water sector. This is more challenging when utilities are only financed by the tariffs they charge to consumers, and the price of water is rather low (K-water, 2018, p. 99). Against that background, access to additional sources of financing, in particular public funding, seems to be very important to spur digitalisation in the drinking water sector (K-water, 2018, pp. 459–460).

### b. Personal data protection and privacy

As explained earlier in this contribution, more accurate and near-to real time consumption data provided by smart meters are a key component of smart water management. At the same time, since smart meters are installed at the home of consumers and taking into account that the data they capture qualify as personal data, water utilities must pay close attention to the limitations and requirements arising from data protection and privacy legal regimes[5] (see Espinosa Apráez & Lavrijssen (2018)).

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[5] Although often used interchangeably, privacy and data protection are two different rights, at least in the European Union legal system. As explained by Dalla Corte (2018, p. 135), while privacy has a substantive nature (protecting private and family life, home and correspondence) data protection has a more formal nature (dictating rules and

In the European Union, the most comprehensive legal framework concerning data protection (and to a lesser extent privacy), is the General Data Protection Regulation (EU) 2016/679 (known as ‘GDPR’). This legislation establishes a set of requirements and principles that must be followed when personal data are processed.

Following the GDPR, ‘personal data’ means “any information relating to an identified or identifiable natural person” (Art. 4 (1)).[6] Data generated by smart meters qualify as personal data to the extent that they contain information relating to an identifiable person. Following an opinion of the Article 29 Data Protection Working Party (a former European Union data protection advisory body), this is usually the case because data generated by smart meters are associated to unique identifiers, such as the meter identification number (Article 29 Data Protection Working Party, 2011, p. 8). This number is “inextricably linked with the living individual who is responsible for the account”, and thus allows to single him/her out from other consumers (Article 29 Data Protection Working Party, 2011, p. 8). In addition, the data collected relate to the consumer’s utility use profile and are used to take decisions that directly affect the consumer (e.g. billing purposes).[7]

Considering that smart meter data qualify as personal data, water utilities in the European Union will have to comply with the provisions of GDPR. In practice, this means that water utilities (in their role of data controllers[8]) will have to take technical and organizational measures to ensure, among others, that:

- The processing of personal data is done in observance of the principles of a) lawfulness, fairness and transparency, b) purpose limitation, c) data minimisation, d) accuracy, e) storage limitation, f) integrity and confidentiality and g) accountability (Art. 5 of the GDPR).
- The processing of personal data is based on at least one of the grounds for lawful data processing in Article 6 of the GDPR, namely: a) consent given by the data subject, b) necessity for the performance of a contract, c) compliance with a legal obligation, d) necessity of protecting vital interests of the data subject or other natural person, e) necessity for the performance of a task in the public interest, and f) necessity for legitimate interests pursued by the controller or a third party.
- The processing of personal data by design and by default is done in compliance with the rules in the GDPR (Art. 25 of the GDPR).

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procedures for data processing to protect certain underlying rights). Moreover, while the scope of data protection is limited to the processing of personal data, privacy covers broader aspects, as here mentioned. For further explanation of the scope of both rights and their somewhat blurry relationship, see Dalla Corte (2018).

[6] An identifiable natural person is someone “who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person” (Art. 4 (1) of the GDPR).

[7] The opinion issued by the Article 29 Data Protection Working Party was prepared having in mind energy smart meters, but the same analysis can be applied to smart water meters.

[8] A data controller is defined by Article 4(7) of the GDPR as “the natural or legal person, public authority, agency or other body which, alone or jointly with others, determines the purposes and means of the processing of personal data; where the purposes and means of such processing are determined by Union or Member State law, the controller or the specific criteria for its nomination may be provided for by Union or Member State law.”

- There will be a record of the data processing activities under the responsibility of the controller (Art. 30 of the GDPR).
- The level of security of the data processing activities is appropriate to the risks involved (Art. 33 of the GDPR).

Compliance with the GDPR is not always a very straightforward exercise if we consider, for example, that some of the principles seem to 'clash' at first sight with core ideas behind big data analytics from which smart water management benefits. For instance, the principle of data minimization might be challenging to reconcile with the need to process large amounts of data to obtain better insights on consumption patterns and the functioning of infrastructures.

Beyond compliance with the GDPR, it is important to consider the limitations arising from the right to privacy, especially when smart water metering is enshrined in legislation or other forms of state regulation. Cuijpers and Koops (2013) analysed the debates concerning privacy during the preparation of the rules that regulate the rollout of smart energy meters in the Netherlands. They highlight the following aspects as having a major role in the initial rejection of the smart metering bills in the Netherlands: 1) the very detailed level (in terms of frequency) of the readings transmitted to the energy utilities; 2) the compulsory nature of the smart metering roll-out (consumers could not refuse installation of the meter); 3) insufficient substantiation concerning the necessity of interfering with consumers' privacy and the compulsory acceptance of the meter; 4) the combination of different functionalities in one meter involved new risks and made the justification of the necessity of the meters less clear. These issues also play a role in the case of smart meter metering in the drinking water sector and should be considered when thinking of regulating it.

Thus, the digitalisation of the drinking water sector comes along with the challenges of applying and complying with substantial and procedural requirements enshrined in data protection and privacy legal regimes.

### c. Cybersecurity

The increased connectivity and reliance on ICT that come hand in hand with digitalisation, creates or worsens exposure to cyber-attacks. While this is a concern that affects any kind of organization making use of ICT, cybersecurity becomes even more crucial when the infrastructures employed to provide essential services are involved.

Cybersecurity can be defined as

> [T]he proactive and reactive processes working toward the ideal of being free from threats to the confidentiality, integrity, or availability of the computers, networks, and information that form part of, and together constitute, cyberspace – the conceptual space that affords digitised and networked human and organisational activities (Adams et al., 2015, p. 26).

The triad 'confidentiality-integrity-availability' is at the core of cybersecurity. As explained by Rasekh et al (2016), in (commercial) IT environments, the most prioritized aspect is 'confidentiality'; but in systems such as water infrastructures, the order of the priorities changes and 'availability' becomes a more crucial aspect. This is because of the great negative impact that an outage of water could cause. When using ICT to monitor but also to remotely operate drinking infrastructures, the unavailability of such systems can lead to the unavailability of the supply of water as well, with disastrous consequences for people.

Horizontal legislation to tackle cybersecurity issues in critical sectors (including the supply of drinking water) was adopted for the first time in the European Union in 2016, with Directive EU 2016/1148 (known as the 'NIS Directive'). The goal of the NIS Directive is to lay down "measures with a view to achieving a high common level of security of network and information systems within the Union so as to improve the functioning of the internal market" (Art. 1 of the NIS Directive). The NIS Directive is primarily addressed to Member States, who should adopt a national strategy on the security of network and information systems, but it is also addressed to operators of essential services and digital service providers.

Suppliers and distributors of drinking water (both public and private) are considered operators of essential services under the NIS Directive (see Annex II, numeral 6 of the NIS Directive), when they: a) provide a service “which is essential for the maintenance of critical societal and/or economic activities”; b) “the provision of that service depends on network and information systems”, and c) “an incident would have significant disruptive effects on the provision of that service” (Art. 5 (2) of the NIS Directive).[9]

Article 14 of the Directive introduces two main obligations for operators of essential services, namely security requirements and incident notification. Regarding security requirements, when transposing the Directive into national law, Member States must ensure that operators of essential services take "appropriate and proportionate technical and organisational measures to manage the risks posed to the security of network and information systems which they use in their operations", having in mind the state of the art (Article 14 (1)). In addition, Member States must ensure that operators of essential services “take appropriate measures to prevent and minimise the impact of incidents affecting the security of the network and information systems used for the provision of such essential services, with a view to ensuring the continuity of those services” (Article 14 (2)). The incident notification obligation entails that operators of essential services should notify "incidents having a significant impact on the continuity of the essential services they provide" to the competent authority or the designated computer security incident response teams (Article 14 (3)).

In sum, digitalisation of drinking water infrastructures comes hand in hand with additional exposure to cyber-attacks that can compromise the availability, confidentiality and integrity of the data and the infrastructures used to process data, which in turn can compromise the availability of the drinking water supply. In view of such risks, water utilities will have to put in place technical and organizational measures to prevent and effectively overcome cybersecurity incidents.

### d. Interoperability and (data) standardisation

Another challenge that comes along with digitalisation is ensuring that the different components of the smart water system are interoperable and that data from different internal and external

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[9] The NIS Directive defines ‘incident’ as “any event having an actual adverse effect on the security of network and information systems” (Art. 4(7)).

sources can be combined and used properly. Several sources report that the level of interoperability and standardisation for smart water management remains low compared to the telecommunications and electricity sector (Anzaldi Varas & ICT4Water, 2018, p. 34; International Telecommunication Union, 2014, p. 40; Lloyd Owen, 2018, p. 215). Lack of system interoperability, common data standards and data processing protocols stands in the way of achieving the potential of digitalisation of drinking water utilities. Furthermore, it hinders collaboration among utilities and between utilities and other actors of the broader water sector by means of data sharing (Lloyd Owen, 2018, p. 215).

## 6. Digitalisation and the role of regulations and other public policies

The provision of drinking water is a highly regulated activity. Regulation and supervision are necessary in this sector to ensure the quality, availability and accessibility of drinking water. Quality can be ensured by means of mandating the monitoring of microbiological, chemical and organoleptic parameters on a regular basis, as exemplified by the Drinking Water Directive in the EU. Espinosa and Lavrijssen (2018) provide an example of a regulatory instrument to ensure availability of drinking water in their analysis of legal framework for this sector in the Netherlands. Dutch drinking water companies are legally obliged to submit before the supervision authority a "delivery plan" which explains "how they will ensure the adequate and sufficient supply of drinking water and how they will address any possible disruptions", and includes the investment plans to improve infrastructures (Espinosa Apráez & Lavrijssen, 2018, p. 168). Finally yet importantly, accessibility is usually safeguarded by creating universal (non-discriminatory) provision obligations and by setting or limiting the tariffs that can be charged by water utilities.

Regulations and other public policies can affect directly or indirectly, positively and negatively, the development and uptake of smart water technologies in the drinking water sector. Lloyd Owen provides examples of direct and indirect interventions or incentives that favour the digitalisation of the drinking water sector:

> Direct policy interventions include cases where governments have specified that a smart water approach should be adopted, such as smart water meters. Indirect policy incentives include tariff policies that encourage demand management along with water and wastewater quality and service delivery standards that are most effectively met through realtime monitoring and management (Lloyd Owen, 2018, p. 200).

A concrete and often cited example of direct policy intervention that stimulated the adoption of smart water technologies is the national smart utility metering plan in Malta, which involved the rollout of smart water (and electricity) meters (OECD, 2017, p. 108). More recently, in the United Kingdom, the National Infrastructure Commission recommended that the government should amend regulations and require drinking water companies "to consider systematic roll out of smart meters as a first step in a concerted campaign to improve water efficiency" (National Infrastructure Commission, 2018, p. 3). The National Infrastructure Commission also suggested other more indirect policy intervention that can stimulate digitalisation of the drinking water sector in the United Kingdom, namely setting a target for the water industry to halve leakage by 2050 (National Infrastructure Commission, 2018).

Another example of a policy intervention that can indirectly encourage further digitalisation of the drinking water sector in the EU is the review of the Drinking Water Directive. It is likely that the new Directive will introduce more strict requirements on the quality of water and on the information that should be provided to consumers (see European Commission, 2019), which might indirectly stimulate the adoption of smart water technologies.

Conversely, digitalisation in the drinking water sector might be hindered by existing regulations if they do not account for the possibilities enabled by new technologies. For example, the original provisions of Drinking Water Directive (enacted in 1998), required that the monitoring of the quality of drinking water had to be conducted by (manually) taking samples at certain points of compliances. This ruled out the possibility of using other ways of monitoring water quality, such as remote sensing techniques. The specifications of the quality monitoring programmes had to be updated by the Commission Directive (EU) 2015/1787 "in the light of scientific and technical progress" (Recital 2), to allow for alternative ways of monitoring, such as measurements recorded by a continuous monitoring process or inspections of records of the functionality and maintenance status of equipment.[10]

Some sources report that existing regulatory instruments in the sector might be ill equipped to enable and facilitate digitalisation and innovation. For instance, a report recently published by EaurEau suggests that the difficulties experienced by utilities in EU countries in accessing and implementing innovative solutions do not lie in the lack of technological solutions, but rather on the policies that regulate "the capacity of water utilities to invest (time and money) in innovation" (EurEau, 2020, p. 3). Similarly, their analysis of the Dutch regulatory instrument for the drinking water sector known as "benchmark"[11], de Goede, Enserink, Worm, & van der Hoek (2016) suggest that such instrument might obstruct innovation. This is the case because the regulatory system and institutional interactions force drinking water companies to value financial aspects as very severe, and, in such a context, benchmarking "rewards the reproduction of the known", hampering innovation (de Goede et al., 2016, p. 1259).

As discussed in this section, public policies and regulations have an important impact on the digitalisation in the drinking water sector. This has been confirmed by studies such as the case study report published by K-water in 2018, which surveyed ten smart water management projects in both developed and developing regions. One of the main conclusions of this report is that policy support and regulations "are a major driver for [smart water management] implementation" and that successful adoption is much easier when smart water management is prioritized in the agenda of governments (K-water, 2018, p. 471).

## 7. Conclusions

This chapter investigated and presented several aspects of digitalisation in the drinking water sector, with special focus on the impact of smart water technologies on the management of infrastructures in this sector. As discussed in this contribution, smart water technologies have the potential to improve the management of infrastructures (in terms of design, monitoring and maintenance), as well as enhancing water demand management, water quality, energy efficiency and customer service.

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[10] Annex II, Part A, par. 2 as amended by Commission Directive EU 2015/1787.

[11] For an explanation of this regulatory instrument used in the Netherlands, see Lavrijssen & Vitez (2015), and Espinosa & Lavrijssen (2018).

In addition to the opportunities presented by digitalisation in the drinking water sector, this chapter also discussed the challenges that come along with the use of smart water technologies. The chapter referred to issues related to financial aspects, cybersecurity, data protection and privacy and interoperability that should be considered and addressed when embracing digitalisation in the drinking water sector. Finally, the chapter discussed the role of regulations and policies in stimulating (or hampering) digitalisation in the drinking water sector.

As discussed in this contribution, digitalisation in the drinking sector is still less pervasive than in other network industries. Although there is already a significant amount of research on the technical feasibility and opportunities of digitalisation in this sector, it seems that broader adoption of smart technologies by drinking water utilities has yet to come. This is partly motivated by factors such as the risk averseness of water utilities, financial challenges and the vertically integrated market structure prevalent in the sector (coordination between different actors is not as indispensable as in other sectors).

Nevertheless, it is expected that digitalisation in the drinking water sector will keep growing, for several reasons. Firstly, smart water technologies offer more efficient ways to deal with the challenges posed by water scarcity, water pollution and ageing infrastructure, compared to non-digitalised approaches. Secondly, it is expected that the price of smart water technologies will decrease as their development and use becomes more widespread. Thirdly, smart water management is getting higher in the agenda of national and supra-national policymakers, as a key strategy to tackle the threats to sufficient and safe supply of water and other environmental policies.

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