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Water law and municipal water in an era of technological development

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1. Introduction

The urbanization process is bound to continue. It is expected that around 68% of the global population will live in urban areas by 2050.[2] This data not only indicates how cities will play a decisive role in socio-economic (and environmental) development in the coming decades but also conceals the emergence of a series of challenges that will soon confront urban conglomerates. Densely populated areas may have a considerable negative impact on natural resources and urban infrastructures. The practical examples include the rapid growth of informal settlements and the problems that are associated with the collection and treatment of larger quantities of solid municipal waste.

Any discussion of the various challenges that arise from growing urbanization should allocate a prominent position to the provision of water. The need to satisfy increasing urban water demands will affect water resources considerably and exert a negative influence on the availability, quality and accessibility of water.[3] Moreover, the effects of climate change and the associated extreme meteorological conditions (e.g., droughts, flash floods and heat waves) may further exacerbate water insecurity. As this prospect looms, the United Nations 2030 Agenda for Sustainable Development has adopted specific targets to ensure that water management can reconcile socio-economic and environmental objectives. Specifically, sustainable development goal ("SDG")

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[2] United Nations, UN 68% of the World Population Projected to Live in Urban Areas by 2050, https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html.

[3] OECD, OECD Environmental Outlook to 2050: The Consequences of Inaction (Paris: OECD Publishing, 2012).

No. 6 promotes universal access to clean water and the sustainable management of water resources. Along similar lines, SDG No. 12 mandates that natural resources be used responsibly, and SDG No. 9 extolls the virtues of developing resilient and sustainable (water) infrastructures.

The international focus on sustainable water management has been paralleled by – or arguably translated into – efforts at more localized levels of governance. Presently, attention is increasingly being paid to means of making cities more sustainable, as urged by SDG No. 11. Cities have traditionally been developed with scant attention to the environment. It is only relatively recently that attention to sustainability came to occupy an important role in urban planning. This point becomes even more important when one considers that the water infrastructures on which these same cities rely are far from ensuring sustainable water management. Most water infrastructures are approaching obsolescence, and they must be repaired or replaced in the coming years. Moreover, the (public or private) organizations that are responsible for these infrastructures tend to suffer from serious underinvestment. It is in this context that the need to rethink urban water management emerges.

One of the most commonly proposed solutions is the creation of smart water cities. The continuous development of artificial intelligence ("AI") applications, together with data-driven innovation[4] and the Internet of Things,[5] is ubiquitous and is characterizing the water sector as much as any other sector of society. The term "smart water management" implies the use of information communication technology ("ICT") components and (almost) real-time data for the development of digital solutions to water management challenges. Specifically, smart water technologies include sensing tools that retrieve data and computing applications for modelling and analytics.[6] The use of smart water technologies can, thus, yield significant efficiencies and gains in sustainability as well as prospective solutions to climate change.[7]

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[4] Please note that the OECD defined the term data driven innovation as "[t]he use of data and analytics to improve or foster new products, processes, organizational methods and markets": OECD, DATA-DRIVEN INNOVATION: BIG DATA FOR GROWTH AND WELL-BEING (Paris: OECD Publishing, 2015), at 17.

[5] Internet of Things refers to machine-to-machine communication.

[6] INTERNATIONAL TELECOMMUNICATION UNION, PARTNERING FOR SOLUTIONS: ICTS IN SMART WATER MANAGEMENT, https://www.zaragoza.es/contenidos/medioambiente/onu/1317-eng_Partnering_for_Solutions_ict_in_Smart_Water_Management.pdf.

[7] Kwi-Gon Kim, *Development of an integrated smart water grid model as a portfolio of climate smart cities*, 3(1) JOURNAL OF SMART CITIES 23 (2019).

Against this background, the conventional, and likely inaccurate, perception of water providers as being responsible solely for water supply has evolved. Now, they are tasked with *sustainable* urban water management, too.[8] Therefore, no discussion of municipal water can prescind from outlining the benefits of technology. By providing more precise and timely information, digitalization and smart water technologies allow for more efficient water consumption without necessitating an expansion of the water supply. These considerations notwithstanding, clear-cut solutions for addressing the challenges of urbanization and achieving sustainable urban water management are yet to emerge. While the technical aspects of smart water technologies seem well developed, policy and regulation on the use of these technologies still poses some (thus far) unaddressed challenges.

This chapter zooms into this issue by illustrating the impact of the technological innovation on municipal water law and the challenges that are associated with it. The remainder of this chapter is structured as follows. Section 2 discusses the burgeoning research on smart cities and smart water management. It also explores the smart water technologies that are most common in urban water management. Section 3 introduces the policy and legal challenges confronting smart cities. Section 4 concludes by inquiring whether the recent technological turn could affect the contemporary conceptualization of water.

2. The technological developments in municipal water law

2.1 Introductory remarks

In the last few years, our own view of cities has tended to change. Cities are no longer conceptualized as mere urban conglomerates but as dynamic centres with socio-economic and environmental objectives of their own. In other words, sustainability concerns have pervaded common notions of municipal development. Any city should, so the argument runs, pursue sustainable development in a responsible way.[9] Technological innovation has significantly supported this shift in conceptualization. The use of ICT components can contribute to the pursuit of a specific set of objectives, rendering any product "smart". Cities are no exception. Accordingly, a discussion of municipal water

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[8] Thomas Boyle et al., *Intelligent metering for urban water: A review*, 5(3) WATER 1052 (2013), at 1053.

[9] See, in particular, SDG No. 11.3.

in the 21st century cannot be separated from an analysis of smart cities and smart water technologies. The following subsections delve into these two topics.

2.2 Smart cities and smart urban water management

Interest in smart cities is burgeoning. Despite this enthusiasm, the term "smart city" is not easy to define. A large body of multidisciplinary scholarship has emerged in which several meanings are attached to that term.[10] While the use of ICT is generally considered to be the defining feature of smart cities, the definition also encompasses other considerations, and its content is liable to depend on the specific aspects of urban life whose link to smart cities a given author wishes to highlight.[11] For example, some authors have complemented the use of ICT with the pursuit of sustainable economic development and city attractiveness[12] or with participatory governance.[13] Others have focused on the quality of life in smart cities and their affordability as a result of the sustainable development objective.[14] For the purposes of this chapter, a smart city is defined as a city that adopts ICT based technologies and non-ICT technologies with a view to sustainable development.

An essential prerequisite for the creation of smart cities is the existence of smart infrastructure systems that provide the public with essential services such as transportation, water and energy.[15] A smart infrastructure system has two constituent parts: a physical network (e.g., roads or railway tracks; water pipelines and energy grids) and a virtual network, which consists of

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[10] Leonidas G. Anthopoulos, *Understanding the Smart City Domain: A Literature Review*, in Manuel Pedro Rodriguez-Bolivar (ed), Transforming City Governments for Successful Smart Cities (Springer International Publishing, ed 2015), 9–21; Vito Albino, Umberto Berardi and Rosa Maria Dangelico, *Smart cities: Definitions, dimensions, performance, and initiatives*, 22(1) Journal of Urban Technology 3 (2015).

[11] Annalisa Cocchia, *Smart and digital city: A systematic literature review. Smart city*, in Renata Paola Dameri and Camille Rosenthal-Sabroux (eds), Smart city: How to create public and economic value with high technology in urban space (Springer, ed 2014) 13–43.

[12] Renata Paola Dameri and Clara Benevolo, *Governing smart cities: an empirical analysis*, 34(6) Social Science Computer Review 693 (2016).

[13] Andrea Caragliu, Chiara Del Bo and Peter Nijkamp, *Smart cities in Europe*, 18(2) Journal of Urban Technology 65 (2011).

[14] Parvez Hayat, *Smart cities: A global perspective*, 72(2) India Quarterly 177 (2016).

[15] Peter Hall, *Creative cities and economic development*, 37(4) Urban Studies 639 (2000).

ICT components (e.g., smart meters; sensors and data).[16] As the International Telecommunication Union Standardization Sector (ITU-T) Focus Group on SSC put it:

> Physical infrastructure is what is truly "physical" – for example, buildings, train tracks, roads, electric lines, gas pipelines, water, factories and the like. Service infrastructure is the service overlay on the physical aspects – for example, a transportation service such as Mass Rapid Transit ((MRT), bus), utilities (water, gas, and electricity), education, and health care. The ICT infrastructure is essential for a successful smart sustainable city – it acts as the "glue" which integrates all the other elements of the smart sustainable city acting as a foundational platform. ICT infrastructure is at the core and acts as the nerve centre, orchestrating all the different interactions between the various core elements and the physical infrastructure.[17]

The virtual network is then a necessary complement to the physical network in smart infrastructure systems and, accordingly, in smart cities. In other words, the lack of a virtual network would render digitalization effort futile, foreclosing the possibility of reaping gains in efficiency. This is true of almost all infrastructure sectors, from transport to gas. However, the pace of innovation varies across sectors. For instance, it was reported that only 18% of smart metering projects worldwide concerned water (and not energy provision) in 2009.[18] This was so because, according to commentators, the water sector tends to resist change.[19] The shift from ordinary urban water management to smart urban water management has, in fact, only just begun. This delay is reflected at the regulatory level. For instance, the roll-out of smart meters in the energy

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[16] Please note that smart technologies usually require some *ad hoc* physical equipment. However, one could comfortably claim that the use of such equipment pertains to the virtual network. See Günter Knieps, *Internet of Things and the economics of smart sustainable cities*, 18(1-2) Competition and Regulation in Network Industries 115 (2017).

[17] International Telecommunication Union, Smart Sustainable Cities: An Analysis of Definitions (Focus Group Technical Report, ITU-T FG-SSC, 2014) at 5.

[18] Sydney Water, National Smart Metering Program Discussion Paper for the Requirements Work Stream (Paramatta: Sydney Water, 2009) – as reported by Boyle et al., *supra* note 8.

[19] Carlos Oliveira Cruz and Joaquim Miranda Sarmento, *Reforming traditional PPP models to cope with the challenges of smart cities*, 18(1-2) Competition and Regulation in Network Industries 94 (2017), at 100. Existing literature tends to emphasize that the water sector tends to hold a rather conservative approach due to its direct relationship with issues of public health and environmental protection. David A. Lloyd Owen, Smart Water Technologies and Techniques: Data Capture and Analysis for Sustainable Water Management (London: John Wiley & Sons, 2018) at 9.

sector already occupies an important position in EU energy law while smart water meters are hardly ever mentioned in EU water law.[20]

However, this does not necessarily reflect a scarcity of technologies that are applicable to the water sector. Sensors, algorithms and big-data analytics are all relevant to urban water systems.[21] By using these technologies, conventional water systems can become more instrumented, interconnected and intelligent. The systems in question can gather, record and analyze data. They can then distribute those data to both the supply side (i.e., operators) and the demand side (i.e., consumers) of the market, where they can be used to diagnose and remedy problems. For instance, water utilities could use this rich trove of information to design new infrastructures (or alter existing ones) in order to respond to the actual demands of the public (e.g., water distribution in peak hours).[22] In short, the full deployment of the existing technological applications would make urban water management smart.

2.3 Smart water technologies

The shift to smart urban water management is underway. Water agencies and water utilities have begun to deploy smart water technologies. One should, however, note that the smart technologies that characterize the water sector are usually applicable to other sectors, too. The examples include the installation of smart meters by energy utilities or the use of sensors in the transport sector. This section, which builds on the existing literature, is not intended as an exhaustive enumeration of all the technologies that are used for smart urban water management. Instead, it briefly explores the technologies that are most commonly discussed in the literature.[23]

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[20] See e.g., Guido Cervigni and Pierre Larouche, Regulating smart metering in Europe: Technological, economic and legal challenges (Brussels: Centre on Regulation in Europe, 2014). In addition, one should note there can certainly be other co-existing reasons behind the neglect of smart meters by EU water policy (e.g., EU water laws in force have been enacted before this technology was mature).

[21] Aditya Dinesh Gupta et al., *Smart water technology for efficient water resource management: A review*, 13(23) Energies 1 (2020).

[22] Thulo Ram Gurung et al., *Smart meters for enhanced water supply network modelling and infrastructure planning*, 90 Resources, conservation and recycling 34 (2014).

[23] Gupta et al., *supra* note 21; Eirini Aivazidou et al., *Smart Technologies for Sustainable Water Management: An Urban Analysis*, 13(24) Sustainability 13940 (2021); Brenda Espinosa Apráez, *Digitalization in the drinking water sector: towards smart water supply management*, in Juan Montero and Matthias Finger

2.3.1 Smart meters

Smart metering is a technology that is associated with smart grids.[24] More precisely, the former is an application of the latter. Smart meters provide utilities and consumers with (almost) real-time consumption data, bypassing the need for manual meter readings.[25] Smart meters have two main features. First, it is possible to acquire high-frequency data at regular time intervals.[26] For instance, it is possible to learn how many liters of water a certain household is using to shower or to clean dishes. Second, that information is made available remotely through a communication system. There is no need for the manual readings that were the norm in the past. These characteristics of smart metering, taken together, increase the volume of information that is available to water utilities and consumers. Previous studies have shown that the use of smart metering has contributed to raising awareness among consumers and led to a reduction in water consumption in the urban areas of Gauteng (South Africa) and Melbourne (Australia).[27]

Therefore, smart metering has significant benefits for several aspects of water management. The information that is gathered facilitates the efficient identification of leakages or other causes of water loss in the network. It predicts and balances demand for water, it serves as a basis for dynamic pricing, and it raises consumers' awareness about water consumption.[28] However, some

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(eds), A MODERN GUIDE TO THE DIGITALIZATION OF INFRASTRUCTURE (Edward Elgar Publishing, ed 2021) 266–288.

[24] Please consider that there are two main types of smart meters: automated meter reading and automated or advanced metering infrastructure. While the former allows data reading by scanning the meters via portable equipment or a vehicle, the latter provides a two-way communication between the meter and the utility company. Please note that some authors consider smart meters only the latter type. See Lloyd Owen, *supra* note 19, at 85.

[25] ELIO ARNIELLA, EVALUATION OF SMART WATER INFRASTRUCTURE TECHNOLOGIES (Inter-American Development Bank, 2017) at 15–16.

[26] Alessandro Cominola et al., *Benefits and challenges of using smart meters for advancing residential water demand modeling and management: A review*, 72 ENVIRONMENTAL MODELLING & SOFTWARE 198 (2015); Boyle et al., *supra* note 8.

[27] Obby Masia and Lowrence D. Erasmus, *Smart metering implementation for enabling water conservation and water demand management: An investigation in Gauteng, South Africa*, 2013 AFRICON (2013); Michael Redhead et al., MELBOURNE RESIDENTIAL WATER END USES WINTER 2010/SUMMER 2012, REPORT 10TR5-001 (Smart Water Fund, 2013).

[28] J. Temido, J. Sousa and R. Malheiro, *SCADA and smart metering systems in water companies; A perspective based on the value creation analysis*, 70 PROCEDIA ENGINEERING 1629 (2014), at 1635–1638; Cervigni and Larouche, *supra* note 20;

authors have claimed that "smart metering can provide a powerful cost reduction instrument for industrial and commercial clients but not for typical households" which may be due to the negligible amount of water that is saved in non-commercial contexts.[29]

2.3.2 Sensor networks

Sensor networks are another technology that is commonly applied in urban water management. Current regulations mandate certain microbiological, chemical, and organoleptic thresholds (e.g., pH), which are indicative of water status.[30] The installation of sensor networks in the water pipes enables monitoring of such parameters easily, the provision of (almost) real-time data and, relatedly, prompt action in cases of contamination or other problems. For instance, recent advances have made it possible to install sensors that can detect and locate water leakages or burst events in the pipeline network promptly. In the central business district of Adelaide (Australia), distributed acoustic sensors were installed to locate and repair cracks before uncontrolled failure.[31] Sensor networks thus represent a marked improvement on the previous technique of collecting samples and analyzing them at regular intervals of time in laboratories.[32] Sensor networks are a considerable improvement on that approach because monitoring water quality under the previous system devoured vast amounts of operators' money and time.[33]

Thulo Ram Gurung et al., *Smart meter enabled informatics for economically efficient diversified water supply infrastructure planning*, 135 Journal of Cleaner Production 1023 (2016).

[29] Cruz and Sarmento, *supra* note 19, at 100.

[30] See, e.g., World Health Organization, Guidelines for Drinking-Water Quality, 4th edition incorporating the 1st addendum (World Health Organization, 2017).

[31] Mark Stephens et al., *Leak-Before-Break Main Failure Prevention for Water Distribution Pipes Using Acoustic Smart Water Technologies: Case Study in Adelaide*, 146 J. Water Resour. Plan. Manag. 05020020 (2020).

[32] Theofanis P. Lambrou et al., *A low-cost sensor network for real-time monitoring and contamination detection in drinking water distribution systems*, 14(8) IEEE Sensors Journal 2765 (2014), at 2765.

[33] One should consider that water monitoring entailed the collection of samples in certain points of the network by operators and the successive analysis of the samples in the laboratory.

2.3.3 Other technological applications

Smart meters and sensors are the most common smart technologies in the water sector. There are other technological applications that are relevant for smart urban water management. Artificial intelligence and machine learning methods can generate other means of developing smart frameworks for monitoring and managing water. For instance, the literature has built a model that forecasts the water flow rate in the wells of Mashhad City (Iran).[34] Moreover, the use of digital output systems, of which smart meters and sensors are a part, to retrieve data can contribute to further refine the development of hydraulic models and (programmed) algorithms. These models and algorithms will then play a significant role in smart urban water management by, for example, predicting changes in water quality and demands or planning future system expansions.[35]

In addition, it is possible to use a combination of different technological tools, such as smart meters, sensors or algorithms, to develop innovative water management methods. This is the case for district metered areas ("DMAs"), a method of identifying and measuring water loss. After dividing the distribution network into a series of sub-metered areas, the management of the utility can measure water supply and consumption individually across the whole distribution network. This method thus allows for the identification of deviations from normal flows and, relatedly, of leakages in the distribution network.[36]

Supervisory control and data acquisition ("SCADA") is another example of automation in the water sector. SCADA consists of a distributed computer system that monitors each element of the water and wastewater system (e.g., transmission pipes, distribution network) remotely by processing up-to-date information and generating reports, alarms and graphs.[37] This computerized management system replaces the older approach, whereby monitoring operations were conducted manually and thus limited by the availability of personnel and characterized by a lack of data integration. SCADA can result in the

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[34] Mohammad Hossein Amini et al., *Presenting a soft sensor for monitoring and controlling well health and pump performance using machine learning, statistical analysis, and Petri net modeling*, ENVIRON. SCI. POLLUT. RES. 1 (2021).

[35] Arniella, *supra* note 25, at 28.

[36] *Id.*, at 18–20. Please note that there are also the so-called pressure management areas, which is "a permanently isolated DMA with pressure control and metering used to control background and unreported leakage and to assist in reducing break frequencies." *Id.*, at 20.

[37] Temido et al., *supra* note 28, at 1631–1632.

adoption of a systemwide approach to monitoring and controlling water and wastewater systems in the urban water cycle.[38]

Some other innovations that can significantly improve urban water management have to do with leak-detection technology. While the scanning of spectral aerial imaging from satellite-mounted sensors or ground-penetrating radars are possible alternatives,[39] perhaps the best-known example of leak-detection technology is smart pigging. This term refers to the use of pipeline inspection gauges (so-called "pigs") in which cleaning functions are combined with advanced inspection functionalities such as the detection of the erosion corrosion and weld anomalies. Smart pigging technology thus has the potential to mitigate the cost of repairs.

The deployment of smart technologies in urban water management is only beginning, but it has already demonstrated its disruptive potential. These technological applications are intended to render urban water management systems more resilient by improving their efficiency and sustainability. Targeted interventions, timely responses to sudden problems that harm the public, and the adoption of effective cost-reduction methods are now possible. Perhaps most importantly, the use of smart technologies may help tackle the problem of leakages in water infrastructures, which affects many urban areas. The cost of a clean water supply for urban areas worldwide is approximately $ 184 billion each year, with at least $ 9.5 billion wasted due to water leakages.[40] Similar benefits would accrue from the use of smart technologies in peri-urban areas, which are particularly important water sources due to the pressures of intensifying urbanization. For example, smart gates would allow for the efficient management of water flows and levels as a consequence of the collection of (almost) real-time data. Despite all of these prospective benefits, smart water technologies are not without limitations. Contemporaneously to the wide deployment of smart (water) technologies, certain policy and legal challenges have begun to emerge. The following section will delve more into this problem.

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[38] *Id.*

[39] For an extensive description of these technologies see Arniella, *supra* note 25, at 24–25.

[40] SENSUS, WATER 20/20 – BRINGING SMART WATER NETWORKS INTO FOCUS (Report by Sensus, 2012).

3. Challenges for smart cities and smart urban water management

3.1 Introductory remarks

Building smart cities is not an easy feat. Digitalization has brought about several significant challenges. Some of them tend to be common to all sectors and are not necessarily inherent to water. This is an important observation because it justifies recourse to the richer literature on said challenges in other sectors. Smart meters offer a striking example. As mentioned previously, the state of the art on smart meters is more developed in the energy sector. This implies that the associated challenges not only materialized earlier in the energy sector, but also that the discussion of the means of addressing them has reached a more mature level. The following subsections discuss the main challenges that smart cities and smart urban water management face. While most of them stem from digitalization, the last (i.e., financing water-related investment) is independent of it.

3.2 Trust, security and privacy

The use of ICT within smart networks goes together with the collection of personal and sensitive information. This aspect should not be overlooked by the actors who are involved in smart urban water management. Responsible actors should ensure the development of security measures that prevent or counteract cyber-attacks. Likewise, the correct and safe handling of confidential information is essential to avoiding breaches of privacy. Enhancing security and privacy would very likely result in a higher number of citizens making active use of technological innovation.[41] Hence, trust in data-driven innovations plays a fundamental role in the successful deployment of smart water technologies among consumers.

Smart technologies are vulnerable to cyber-attacks. Besides, attacks that target smart water technologies may have serious consequences not only for data protection, but also for water security. Water is an essential resource, and any cyber-attack that threatens to disrupt its provision can occasion significant harm to society. Against this background, certain jurisdictions have begun to adopt legislation that aims at a high level of security for network and information systems. This type of regulatory intervention is commonly adopted at

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[41] Matthew Moy de Vitry et al., *Smart urban water systems: what could possibly go wrong?*, 14(8) ENVIRONMENTAL RESEARCH LETTERS 081001 (2019).

a higher level of governance. However, given the high fragmentation and localization of service providers, it produces its main effects at the municipal level. For instance, the EU adopted the NIS directive, which is addressed to member states and essential services operators, including (local) water providers.[42] According to Article 14, (local) water providers should adopt "appropriate and proportionate" measures that would allow them to promptly manage the risks that stem from cyber-attacks against their network and information systems promptly as well as to ensure the continuity of their services.[43] Hence, this shows that the authorities are aware of the need to provide a basic regulatory framework that facilitates solutions to protect network infrastructures and systems from cybersecurity incidents such as water cuts. Relatedly, there is a need from the actors involved in the water sector to direct funds to the technical assistance for the prevention or management of these threats. This was, for example, the case for the US Environmental Protection Agency, which set up the Drinking Water State Revolving Fund to assist actors who are involved in the development of cybersecurity practices for the drinking water system.[44] Section 3.4 discusses this matter further.

The information that is retrieved by digital output systems is very important for water providers. For instance, the information from smart meters could allow water utilities to reconstruct consumption patterns. The information that would fall into the hands of water providers may be particularly confidential, with the risk of violating consumers' privacy. It is no surprise that, in most jurisdictions, these data may fall under the definition of "personal data" or "personal information".[45] This makes accessing and using the data possible only when water utilities comply with privacy laws and data security requirements.[46] Therefore, a balance must be struck between data minimization to

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[42] Directive (EU) 2016/1148 of the European Parliament and of the Council of 6 July 2016 concerning measures for a high common level of security of network and information systems across the Union OJ L 194/1.

[43] Please note that Article 14 includes an obligation to notify the incidents having a significant impact on the services, too.

[44] See, e.g., 42 U.S.C. §300j-12 and ENVIRONMENT PROTECTION AGENCY, SUPPORTING CYBERSECURITY MEASURES WITH THE DRINKING WATER STATE REVOLVING FUND, https://www.epa.gov/sites/default/files/2019-10/documents/cybersecurity_fact_sheet_final.pdf.

[45] For the EU, see Article 4(1) of GDPR and Opinion 12/2011 on Smart Metering (WP 183). For Canada, see Personal Information Protection and Electronic Documents Act S.C. 2000, c. 5 – and, for Ontario, Freedom of Information and Protection of Privacy Act.

[46] Espinosa Apráez, *supra* note 23, at 277.

protect consumers' privacy and granular data collection to secure efficiency and sustainability gains.[47]

In addition, privacy concerns may still exist regardless of the existing regulatory framework and could possibly affect the willingness of citizens to install smart technologies in their homes. A notable example is provided by the privacy concerns that have caused considerable resistance to the compulsory installation of smart energy meters around the world, including in North America and the Netherlands.[48] It is for this reason that water providers, aided by municipalities, may consider using soft law instruments (e.g., guidelines and common standards) to increase citizens' trust. For instance, one proposal that has been advanced entails reducing the frequency of smart meter readings. Limiting the amount of data that is collected would prevent utilities from identifying consumption patterns at too high a level of precision.[49] Likewise, utilities may commit to only use data at the aggregate level, thus ensuring data anonymity – a practice that already enjoys official backing in jurisdictions such as California.[50] Once again, the role of municipalities in incentivizing the adoption of these soft-law instruments and in monitoring their implementation may turn out to be decisive.

3.3 Interoperability

Interoperability is an important feature of a well-functioning digital environment. The virtual components that are applicable to the water sector should be treated as interconnected, rather than perceived as isolated entities. In fact, the fragmentation of the water sector tends to lead to the adoption of many different digital solutions to similar issues. This situation thus causes a harmonization gap and limits cooperation between the various stakeholders. The use of interoperable components, whereby data from different sources are

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[47] *Id.*

[48] David J. Hess, *Smart meters and public acceptance: comparative analysis and governance implications*, 16(3) HEALTH, RISK & SOCIETY 243 (2014); Laura Draetta and Bastien Tavner, *De la «fronde anti-Linky» à la justification écologique du smart metering: retour sur la genèse d'un projet controversé*, 82 LIEN SOCIAL ET POLITIQUES 52 (2019); Colette Cuijpers and Bert-Jaap Koops, *Smart metering and privacy in Europe: Lessons from the Dutch case*, in SERGE GUTWIRTH ET AL. (eds), EUROPEAN DATA PROTECTION: COMING OF AGE (Dordrecht: Springer, ed 2013) 269–293.

[49] Dasom Lee and David J. Hess, *Data privacy and residential smart meters: Comparative analysis and harmonization potential*, 70 UTILITIES POLICY 101188 (2021), at 101194.

[50] *Id.*

combined, would enable the opportunities that smart technologies provide to be harnessed. In other words, interoperability would allow for the better integration of water processes, including more efficiency and improvements in security.[51] However, this is a tall order.

There are two significant barriers to interoperability. From a technical perspective, interconnected virtual networks require a certain level of data standardization (e.g., having common data standards such as the metric system), as well as common standards and protocols for data communication and transmission. Common data standards would, for example, allow utilities to adopt smart systems in any catchment area without the need to reconcile various physical or chemical measures.[52] However, the level of standardization and interoperability in the water sector is not as high as in other sectors, such as telecommunications or energy.[53] A second barrier refers to the existence of different datasets that are owned by different organizations in the water sector. The opportunity to connect each and any of these datasets is not easy to exploit due to the heavy regulation that typifies the sector. Municipal intervention may help the former barrier to be addressed by setting up semi-formal forums at which all of the actors that are involved in water distribution could discuss means of improving data standardization.

3.4 Water security and equity

Smart meters and water sensors are oftentimes presented as technologies with an immense potential for urban water management. Efficiency gains and decreases in the volume of non-revenue waters in the network mean that smart water technologies would – or so the argument runs – lead to lower costs and higher incomes for utilities. These should, in principle, translate into constant customer rates, with positive spillover effects for water security and equity. Unfortunately, the reality has not entirely lived up to these expectations.

Smart technologies can also provide consumers with precious information about their consumption patterns. For instance, the consumption feedback that is provided to consumers would spur water saving behavior so that water crises may be averted. However, consumers do not seem to have been involved

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[51] Andreas Hauser and Florian Roedler, *Interoperability: the key for smart water management*, 15 Water Supply 207 (2015).

[52] Lloyd Owen, *supra* note 19, at 215.

[53] International Telecommunication Union, *supra* note 17, at 40.

properly in this information loop.[54] Social science scholarship is currently exploring means of improving the quality of the information that is provided, in terms of content and granularity, with a particular view to the type of audience that receives the feedback. For instance, it has been argued that highlighting narratives of the successes and failures of smart water technologies may enhance the understanding and awareness among consumers.[55] A contextual problem is that some segments of society resist the implementation of the smart system because they claim that this technology would not focus on addressing their basic needs and the redistribution of economic resources but only ensure that wealthy individuals can continue to use a higher amount of water for their lifestyles, which are not compatible with environmental conservation.[56]

An additional issue that is caused by the current use of big data is that the tendency to describe the dynamics of water systems in functional terms is reinforced.[57] This technical-oriented approach carries the risk of overlooking and even neglecting issues that are more socio-political in nature, thereby oversimplifying the approach to water management.[58] At the same time, it may support the existing assumptions in water management practices that inhibit critical reflection on the developments that digitalization has spurred, a point to which the exposition returns in its conclusion.

Furthermore, it may well be the case that, when it comes to water law, cities are concerned with issues other than digitalization. For example, efficiency and sustainability gains may be perceived as secondary in comparison to other, more basic needs: previous research has shown that, in developing cities, the prospect of implementing smart sensor networks in the water system

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[54] A. L. Sønderlund et al., *Using smart meters for household water consumption feedback: Knowns and unknowns*, 89 Procedia Engineering 990 (2014).

[55] Moy de Vitry et al., *supra* note 41.

[56] Chris J. Martin, James Evans and Andrew Karvonen, *Smart and sustainable? Five tensions in the visions and practices of the smart-sustainable city in Europe and North America*, 133 Technological Forecasting and Social Change 269 (2018) at 271.

[57] Claire Hoolohan et al., *Resocializing digital water transformations: Outlining social science perspectives on the digital water journey*, 8(3) Wiley Interdisciplinary Reviews: Water 1 (2021).

[58] Zoë Sofoulis, *Skirting complexity: The retarding quest for the average water user*, 25(6) Continuum 795 (2011). At a more general level, see Paul Dourish and Edgar Gómez Cruz, *Datafication and data fiction: Narrating data and narrating with data*, 5(2) Big Data & Society 1 (2018).

has had to give way to the construction of toilets for sanitation reasons.[59] At the same time, a digital technology that is specifically designed to improve water equity may create other issues. For certain authors, this occurred when smartcard-operated water ATMs were installed in Soweto (South Africa). These water ATMs allowed providers to monitor consumption. While this may increase accountability in principle, it arguably violates basic dignity principles and pushes individuals to control their daily consumption carefully.[60]

3.5 Financing water-related investment

Financial challenges must also be considered. It is often argued that the use of smart technologies would make water management more sustainable and less expensive. This proposition, however, does not reflect the initial investments that are needed for digitalization. Although the price of installing smart technologies throughout the water infrastructure tends to decrease over time, smart technologies entail high initial investments.[61] It is necessary to build adequate infrastructure and to use smart devices that allow for the collection, transmission, storage and analysis of large datasets. Beyond these costs, water utilities must employ skilled personnel who can work with and maintain the said technological applications, as well as securing cybersecurity.[62]

The considerable financial investment that smart urban water technology demands does not constitute an entirely novel challenge for the water and wastewater sector. The construction and maintenance of water infrastructure has always been capital intensive with high sunk costs, while the level of cost recovery for the water services is generally low. Therefore, smart urban water management notwithstanding, water providers need to make considerable initial investments with expected long pay-back periods.[63]

This financial challenge is complicated further by the nature of water projects. These tend to be context specific (e.g., wastewater treatment plant and floodplain), thereby increasing transaction costs for the various stakeholders

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[59] Gupta et al., *supra* note 21, at 15.

[60] Antina von Schnitzler, DEMOCRACY'S INFRASTRUCTURE: TECHNO-POLITICS AND PROTEST AFTER APARTHEID (Princeton: Princeton University Press, 2016) at 168–195.

[61] Sven Eggimann et al., *The potential of knowing more: A review of data-driven urban water management*, 51(5) ENVIRONMENTAL SCIENCE & TECHNOLOGY 2538 (2017); Lloyd Owen, *supra* note 19, at 87.

[62] Moy de Vitry et al., *supra* note 41.

[63] The investments are usually financed through high loans with interest rates for a relatively long period.

who are involved and generating uncertainties due to the lack of data on comparable projects that have been financed in the past. Relatedly, each water project may affect a number of competing interests which not only prevents the actors from reaching agreements, but also causes them to fail to attract the requisite financing. It may well be that a profitable investment does not ensure (or maximize) social and environmental objectives. For instance, it has been observed that reconciling accessibility and cost recovery in water services has proven challenging in most Asian urban projects, with investment failing even further as a result.[64]

Numerous instruments have been adopted over time to address these challenges. For instance, blended finance has recently been promoted as a solution for attracting financing for water in developing countries.[65] Traditionally, private-sector involvement in the financing and the direct operation of urban infrastructures has been used as a response to the problem of capital scarcity. Specifically, some consider public-private partnerships ("PPPs") to represent an adequate compromise between the need to protect the public interests and demand for private capital and expertise.

Although there is no standard definition of a PPP, there are three main types of PPP agreements, namely management contracts, lease contracts and concessions. In management contracts, the management and execution of certain tasks are outsourced to the private sector for a relatively short period of time in return for a generally fixed fee that is paid by the awarding authority. Under lease contracts, private operators assume responsibility for managing and executing certain tasks, and the awarding authority finances investments. The private operator pays a fixed rent to the awarding authority. Concessions equip private operators with the right to use utility assets for a long period of time

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[64] ASIAN DEVELOPMENT BANK, A GOVERNANCE APPROACH TO URBAN WATER PUBLIC-PRIVATE PARTNERSHIPS: CASE STUDIES AND LESSONS FROM ASIA AND THE PACIFIC (ADB, 2022), at 29. A similar point can be raised in international water law. See, e.g., Ellen Hey and Alberto Quintavalla, *How international water law connects to environmental and human rights*, in JOSEPH DELLAPENNA AND JOYEETA GUPTA (eds), Encyclopedia of Water Law (Edward Elgar, ed 2021) 190, at 201.

[65] Blended finance can be defined as "the strategic use of development finance for the mobilisation of additional finance towards sustainable development in developing countries." See OECD, FINANCING WATER: INVESTING IN SUSTAINABLE GROWTH (Paris: OECD, 2018), at 11.

in exchange for the payment of a concession fee to the contracting authority. The ownership of the assets, however, remain with the contracting authority.[66]

These three arrangements are not defined clearly in practice. Each type may exhibit certain (sub)specificities. In addition, it is possible to observe an increasing use of design–build–operate contracts in some parts of Asia in recent years.[67] Another model that can help small- and mid-sized cities is that of performance-based construct-and-operate contracts. These contracts can attract private operators and their private capital and expertise.[68] These are positive developments for municipalities, which may enjoy a differentiated menu of options when it comes to allocating risks and to managing their responsibilities. Attention must be paid to lacunae in, among others, competition or procurement laws. A related challenge for smart urban water management is that embracing digitalization may depend chiefly on local political preferences since agreements with PPPs tend to be localized.[69] It is therefore necessary to involve and integrate all the concerned stakeholders into these decision-making processes (e.g., municipalities and institutions at a higher governance level, members of the public and specific communities, and economic operators).

4. Conclusion

Water is an essential resource that is being depleted at an alarming rate around the world. Urbanization, together with climate change, will cause this trend to deteriorate even further. Smart cities have emerged as a potential means of counteracting this process. Smart urban water and wastewater management are intended to ensure that water is used more efficiently and that the amount of untreated water that is discharged into waterways is reduced. Relatedly, smart technologies improve water conservation. The resulting savings can then be deployed to securing the water supply and to serving those marginalized individuals with insufficient access to water and sanitation.

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[66] A similar yet distinct contract is the so-called build-operate-transfer contract whereby private operators are responsible for developing and managing a specific asset, and not the whole network.

[67] Asian Development Bank, *supra* note 64, at 8.

[68] *Id.*, at 20.

[69] Eduardo Araral, *Why do cities adopt smart technologies? Contingency theory and evidence from the United States*, 106 Cities 102873 (2020).

This positive outlook on digitalization should be complemented with a discussion on the challenges that (smart) cities face. These challenges mostly pertain to the realms of policy and law, raising issues that range from privacy concerns to the attribution of a secondary role to water equity. In addition, it is possible to identify a common trend in all of these challenges – contextual factors are important to smart urban water management. In fact, digital technologies tend to foster the local dimension of water governance, which shows that effective solutions are more likely to be found at the local level.[70]

This point is particularly interesting if placed within the context of contemporary discussions on the conceptualization of water. The extant literature argues that modern societies tend to view water as a single homogeneous substance and to pay scant attention to its contextual features.[71] This conceptualization, which accounts for the modern understanding of water, emerged after certain developments in the 18th and 19th centuries (i.e., the Chemical Revolution that conceptually reduced water to the status of a chemical compound; modern epidemiology; and the Industrial Revolution).[72] However, some scholars have started advancing the claim that there are signs of a return to a more fragmented conception of water.[73] The digitalization of the water sector and the creation of well-functioning smart cities seem to lend support to this hypothesis.[74] It would be welcome that scholars would research this matter more closely.

Another discussion point remains to be introduced for the purposes of future research. The realization of smart urban water management must be premised on a holistic approach. For example, energy considerations must be prominent – the extraction, treatment and distribution of water require considerable amounts of energy. Likewise, water use is oftentimes tied to household energy consumption. One need only think of the appliances (e.g., washing machines, dishwashers and bathtubs) that supply water through energy-intensive pro-

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[70] Hoolohan et al., *supra* note 57, at 12.

[71] Jamie Linton, WHAT IS WATER? THE HISTORY OF A MODERN ABSTRACTION (UBC Press, 2010); Alberto Quintavalla, *Roman Law and Waters: How Local Hydrography Framed Regulation*, 15(2) WATER ALTERNATIVES 457 (2022).

[72] Jamie Linton, *Modern water and its discontents: a history of hydrosocial renewal*, 1(1) WILEY INTERDISCIPLINARY REVIEWS: WATER 111 (2014); Christopher Hamlin, "*Waters" or "Water"? – Master narratives in water history and their implications for contemporary water policy* 2(4-5) WATER POLICY 313 (2000).

[73] Eran Feitelson, *What is water? A normative perspective*, 14(S1) WATER POLICY 52 (2012); Quintavalla, *supra* note 71.

[74] Hoolohan et al., *supra* note 57, at 12.

cesses.[75] Therefore, it would be wise to incorporate energy into the discussion of smart water technologies. The energy-water nexus would then be a useful framework. It shows how energy and water are linked inextricably and ensures a more holistic view on the matter. Relatedly, it will become important to explore policy and regulatory avenues for facilitating the integration of all of the various data that smart technologies collect from different infrastructure sectors (e.g., water, energy and waste).

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[75] Damien P. Giurco, Stuart B. White and Rodney A. Stewart, *Smart metering and water end-use data: Conservation benefits and privacy risks*, 2(3) WATER 461 (2010).