PART 1

SMART WATER CITIES

Cities around the world are hubs of innovation and creativity. They are at the centre of worldwide economic growth, trade and finance exchanges, communication, logistics, and are the homes for billions of people. With urban income levels about 21% higher than the national average, cities concentrate countries' wealth. They are also axes of cultural influence, driving transformation and reforms in all domains. With their great power of attraction, population of cities' is rising worldwide, expected to account for over 60% of the world's total population by 2030 (UNDESA Population Division, 2019; OECD, 2019).

Part 1 of this report examines the essential features of cities today and details the water challenges currently faced and likely to be confronted in the future. It also investigates the functions that water fulfils in the urban environment, and how ICTs can contribute to improving those functions. A definition of a Smart Water City is proposed following a discussion on the meaning of "smart development". This part of the report also presents different city cases from countries around the world to illustrate the urban water challenges and the technological and non-technological solutions that cities have put in place, including national and/or local policies and strategies. These case studies are further examined in the Annex of the report.

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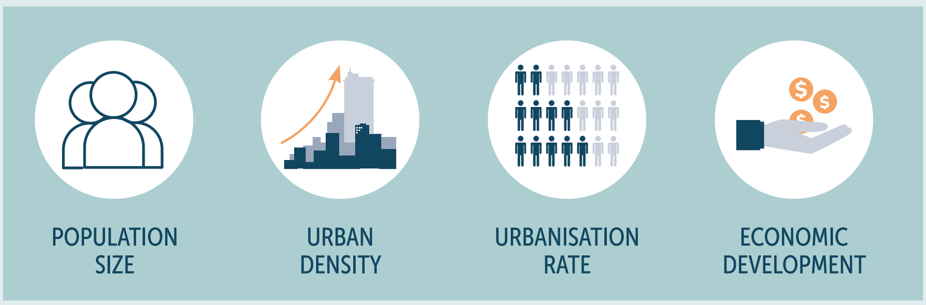
CHAPTER 1
CITIES: URBAN CHALLENGES AND GLOBAL AGENDAS

1.1. Cities and urban features

What is a city? More than 50% of the world population is considered to live in urban areas and yet, the characteristics of these areas vary enormously. Cities vary in terms of size and density, in socio-economic circumstances, in cultural factors, in governance, etc. Some have been built recently, others were inaugurated thousands of years ago. They vary in their natural features–climate, geography, orography, access to natural resources–as well as in their socio-economic factors and make up–industrialisation, urbanisation, and technological skill. Moreover, cities are constantly changing, adapting to shifting circumstances and developing their own features and characteristics. As such diverse circumstances concur, defining a city is not an easy task; however, the specialist literature identifies cities as made up of of three main elements: citizens, activities, and land/facilities (Lynch, 1960; Korea Planning Association, 2016). These elements, combined, derive into a definition of a city as a place where people gather and live, carry out their economic activities, and create and recreate their social and cultural values. Thus, the goal of an urban planning project should be to facilitate the ability for those people to undertake their individual and collective life projects in good health and freedom.

Understanding the different features of a city is important for adequate urban management. Ensuring that city inhabitants enjoy appropriate services such as water supply, water drainage, or sanitation, is significantly different in densely populated or in sprawling metropolitan areas, as well as in greener or in highly built-up areas. Some of the more relevant features of cities and urban trends are examined below. These include population size, urban density, rate of urbanization, economic development, and status as a new or old city.

Figure 2. Features of Cities



1. Population size

Cities vary in terms of their population (UN-Habitat, 2020b). For this, we distinguish between the following categories:

- **Megacities:** cities of over 10 million inhabitants
- **Large Cities:** from 5 to 10 million inhabitants
- **Medium-Sized Cities:** from 1 to 5 million inhabitants
- **Small Cities:** 500,000 to 1 million
- **Large Towns:** 300,000 to 500,000
- **Urban Settlements:** fewer than 300,000 inhabitants

Over the past fifty years, the number of people living in large urban clusters have increased and are expected to continue. In 1970, 63% of the total population lived in rural areas. 20% lived in urban settlements with fewer than 300,000 inhabitants, and the remaining 17% resided in large towns and cities. Nearly 50 years later, however, in 2018, thirty-three megacities in Africa, Asia, Europe, Latin America, and North America accounted for 7% of the world's total population; large cities concentrated another 4% of the global population; medium sized cities held 12% of the world population; small cities had around 5% of world population; large towns concentrated 4% of world population; and urban settlements with fewer than 300,000 inhabitants, brought around 23% of world population. Thus, while 36% of the world's population lived in cities in 1970, more than half of the population did so in 2018. The data shows that by 2018, the urban population had increased by almost three billion people, from 1.3 billion in 1970 to 4.3 billion in 2018. The overall population of megacities, although comparably small, soared almost tenfold, growing from 55 million in 1970, to 529 million inhabitants in 2018. This trend is likely to continue. Although the impact that the covid pandemic will have on population trends is unknown, according to estimates urban population will reach 5.5 billion people by 2035 – 62% of the total world population (UN, 2019). Every region is expected to become more urbanized. Over 95% urban growth is projected in the less developed regions of East Asia, South Asia, and Africa, while already highly urbanized regions are anticipated to grow at a slower rate (UN-Habitat, 2020a) (Table 1).

Table 1. Population Distribution of the World, by Rural/Urban Area of Residence and Size Class of Urban Settlement, 1970, 1990, 2018, and 2030.

Area of residence and size class of urban settlement (number of inhabitants)	Population Million - (%)				Example
	1970	1990	2018	2030	
Total	3701 (100)	5331 (100)	7633 (100)	8551 (100)	
Urban area	1354 (36.6)	2290 (43.0)	4220 (55.3)	5167 (60.4)	
Megacities (10 million or more)	55 (1.5)	153 (2.9)	529 (6.9)	752 (8.8)	Beijing (China); Istanbul (Turkey); Jakarta (Indonesia); **Mumbai (India)**; Tokyo (Japan)
Large Cities (5 million to 10 million)	107 (2.9)	156 (2.9)	325 (4.3)	448 (5.2)	**Hong Kong (China)**; London (UK); **Ningbo (China)**; **NYC (USA)**; Seoul (ROK)
Medium-Sized Cities (1 million to 5 million)	244 (6.6)	467 (8.8)	926 (12.1)	1183 (13.8)	Berlin (Germany); **Ciudad Juarez (Mexico)**; Kuala Lumpur (Malaysia); Paris (France); Rome (Italy)
Small Cities (500,000 to 1 million)	131 (3.5)	208 (3.9)	415 (5.4)	494 (5.8)	Amsterdam (Netherlands); Colombo (Sri Lanka); **Nakuru (Kenya)**; Stockholm (Sweden); Vancouver (Canada)
Large Towns (300,000 to 500,000)	87 (2.3)	159 (3.0)	275 (3.6)	320 (3.7)	Addis Ababa (Ethiopia); Bonn (Germany); Canberra (Australia); Cape Town (South Africa); Sochi (Russia); Zurich (Switzerland)
Urban Settlements (Fewer than 300,000)	730 (19.7)	1147 (21.5)	1750 (22.9)	1971 (23.1)	**Algarrobo (Spain)**; **Busan Eco Delta City (ROK)**; **Heredia (Costa Rica)**; Siem Reap (Cambodia); Thimphu (Bhutan)
Rural area	2346 (63.4)	3041 (57.0)	3413 (44.7)	3384 (39.6)	

* Case Study Countries are shown in bold / Source: UNDESA Population Division, 2019

Figure 3. Urbanization Trend

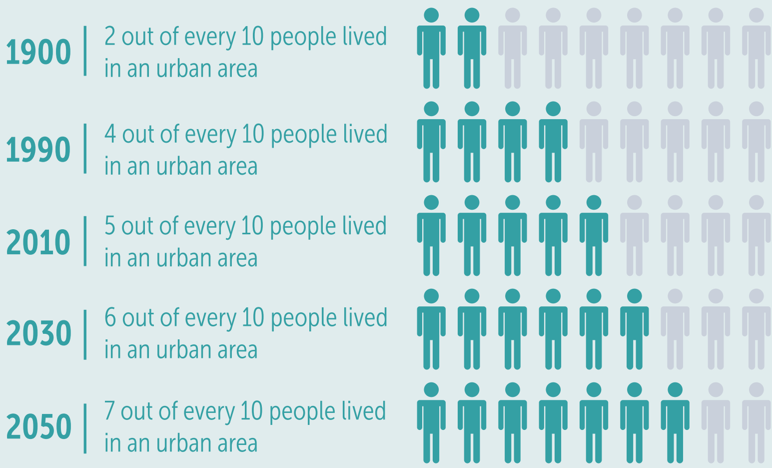
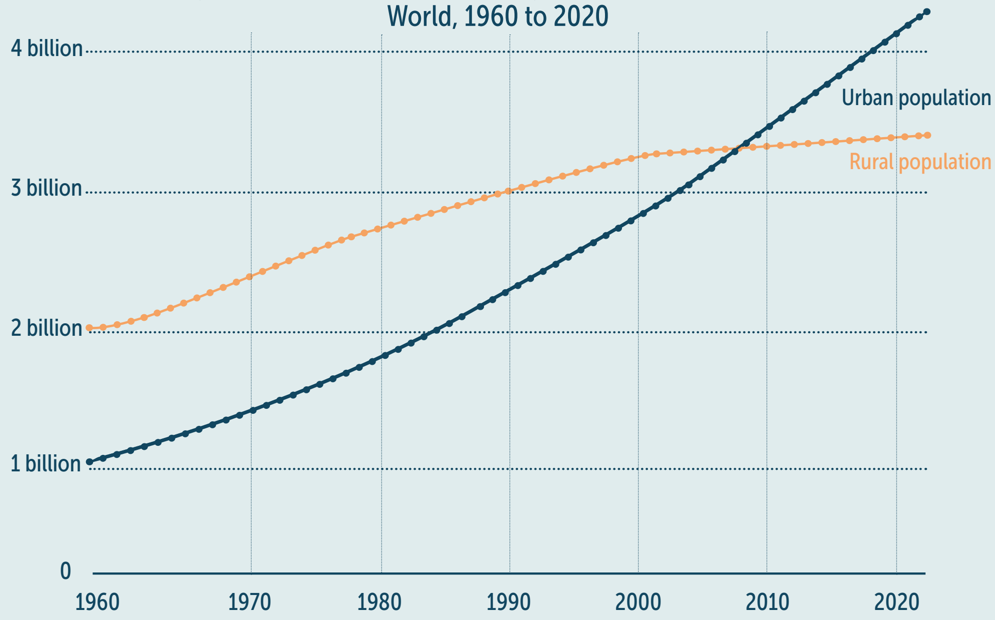


Figure 4. Number of People Living in Urban and Rural Areas, World, 1960 to 2020



Source: World Bank based on data from the UN Population Division.
Note: Urban populations are defined based on the definition of urban areas by national statistical offices.
Our World in Data.

2. Urban density

Urban density refers to the number of people living in a city per unit area. Four degrees of urban density are identified (UN-Habitat, 2020b):

- **Very High-Density Cities:** more than 8 000 inhabitants/km^2
- **High Density Cities:** between 6 000 and 8 000 inhabitants/km^2
- **Dense Cities:** Between 4 000 and 6 000 inhabitants/km^2
- **Lower-Density Cities:** fewer than 4 000 inhabitants/km^2

Table 2. Examples of Urban Density of World Cities

Urban Density	Examples
Very High-Density Cities (More than 8000 inhabitants/km^2)	Colombo (Sri Lanka); **Heredia (Costa Rica)**; Jakarta (Indonesia); **Mumbai (India)**; **New York City (USA)**; Paris (France); Seoul (ROK)
High Density Cities (Between 6000 and 8000 inhabitants/km^2)	**Busan Eco Delta City (ROK)**; **Hong Kong (China)**; Kuala Lumpur (Malaysia); Tokyo (Japan)
Dense Cities (Between 4000 and 6000 inhabitants/km^2)	Berlin (Germany); **Ciudad Juarez (Mexico)**; London (UK); Stockholm (Sweden); Thimphu (Bhutan); Vancouver (Canada); Zurich (Switzerland)
Lower-Density Cities (Fewer than 4000 inhabitants/km^2)	**Algarrobo (Spain)**; Amsterdam (Netherlands); Beijing (China); Bonn (Germany); Canberra (Australia); Cape Town (South Africa); Istanbul (Turkey); **Nakuru (Kenya)**; **Ningbo (China)**; Rome (Italy); Sochi (Russia)

* Case Study Countries are shown in bold

Information about urban density around the world shows that cities everywhere are dense, but not equally so. In general, larger cities tend to be denser. In addition, a correlation is established between the income of a country and the density of its cities: cities in low-income countries are almost four times denser than cities in high-income countries. Globally, cities have continuously become denser over the past 40 years. The increasing density of large and very large cities (of more than 1 million inhabitants) is the main driver of the global increase in population density (OECD & European Commission, 2020).

Urban density has implications on urban services: low-density cities need to spend more on infrastructure to offer the same level of service, as there is more space to cover. The existing evidence suggests that a shift from moderate to low density leads to a bigger increase in costs, while a shift from high to moderate levels of density has less of an impact (OECD and European Commission, 2020).

3. Rate of urbanization

As well as measuring the population size and density, cities also vary according to the average rate of change of the urban population over a period of time (i.e., how fast a city grows). The rate of urbanization between 1950 and 2018 around the world was 0.92% per year on average. However, urbanization has occurred at faster rates in less developed regions, which have reached a higher number of larger cities in substantially less time than developed countries (UN, 2019). Conversely, in many developed countries, cities are shrinking. Examples of this exist in USA, Japan, and Europe. Declining population is often linked to processes of de-industrialisation and migration (UN-Habitat, 2020b).

Knowing the rate of urbanization for a city can illuminate potential challenges that the city might have in providing adequate water services to the population. A city growing at a greater rate, for example, may have difficulties in ensuring the supply of WASH services to its population. Conversely, cities with declining populations face a different type of challenge, caused by the difficulties of maintaining an infrastructure and a level of service originally planned for a larger population. ICTs may provide adequate solutions to shrinking cities via remote services.

Table 3. Rate of Urbanization in the World, by Development Group, Selected Years, and Periods, 1950-2050

Development Group	Rate of Urbanization (%)				
	1950-1970	1970-1990	1990-2018	2018-2030	2030-2050
World	1.06	0.80	0.90	0.74	0.62
More Developed Regions	0.99	0.40	0.30	0.28	0.31
Less Developed Regions	1.78	1.61	1.33	0.94	0.73

Source: UNDESA Population Division, 2019

4. New or existing city

Cities' population can grow either through densification within old city borders, or through the creation or expansion of cities on unbuilt land. Studies on the topic show that on average, 65-70% of population growth of cities since 1975 has occurred through densification. This pattern has become stronger over time. In the period from 1975 to 1990, 65% of city population growth had happened within cities' old boundaries. Between 2000 to 2015, however, the percentage increased to 71%, while 29% reflected the urbanization of new areas (OECD, 2020a).

The challenges that these two different strategies create on urban infrastructure and city planning are very different and need to be considered. Urban densification imposes pressures on old infrastructure, which will likely need repairing and retrofitting to meet new demands. For its part, new urban development allows the installation of new smart infrastructure from scratch, but also requires an appropriate estimation of future uses and needs. These two different endeavors entail different costs, knowledge, and resources.

On this topic, the UN advises that when new developments are needed to accommodate population growth, they should be established at the periphery of existing cities and with the purpose of promoting compact and contiguous urban developments (UN, 2019). The objective is to avoid creating whole new cities from zero, which tends to be very expensive. It is also argued that new developments should be on lands of lower environmental and agricultural value, to minimize the environmental impact that urbanisation and city expansion may have on nature. The UN also argues for a proper design of new urban developments to make them both liveable and sustainable (UN, 2019).

5. Economic development

Cities also vary according to their economic development. The World Bank has adopted a classification that assigns the world's economies to four income groups: low, lower-middle, upper-middle, and high-income countries. The classifications are updated each year based on Gross National Income (GNI) per capita. The values in 2020 were the following:

- Cities in high income countries have a GNI per capita superior to 12,535 USD.
- Cities in upper-middle income countries have a GNI per capita between 4,046 and 12,535 USD.
- Cities in lower-middle income countries have a GNI per capita between 1,036 and 4,045 USD.
- Cities in low-income countries have a GNI per capita below 1,036 USD.

Table 4. Examples of Economic Development of World Cities

Economic Development	Example
High Income Countries (More than 12,535 USD GNI Per Capita)	Australia; Canada; France; Germany; **Hong Kong (China)**; Italy; Japan; Netherlands; **ROK; Spain**; Sweden; Switzerland; UK; **USA**
Upper-Middle Income Countries (Between 4,046 and 12,535 USD GNI Per Capita)	**China; Costa Rica**; Malaysia; **Mexico**; Russia; South Africa; Turkey
Lower-Middle Income Countries (Between 1,036 and 4,045 USD GNI Per Capita)	Bhutan; India; Indonesia; **Kenya**; Sri Lanka
Low Income Countries (Less than 1,036 USD GNI Per Capita)	Afghanistan; Ethiopia; Liberia; Somalia; Yemen

*Case Study Countries are shown in bold

Both the socio-economic and technological performance of a country are defined by its degree of economic development. Economic development is a critical component with a large impact on industrial attainment and innovation, educational and cultural performance, financial development, and an improved quality of life. For this, we expect high income cities to have more access to the technologies as well as the financial resources required to develop SWM in urban developments. We expect lower income cities will be more likely to face difficulties. Proposals to introduce solutions in cities with different degrees of economic resources need to be responsive to these circumstances to ensure overall effectiveness and sustainability. Thus, while introducing smart solutions in high-income cities might involve further expanding its ICT infrastructure, low-income cities might give priority to smart solutions for flood prevention and stable water supply. Smart urban water planning is aware of these financial constraints.

1.2. Key challenges in world cities today

Regardless of their different and specific urban features, world cities today are facing common challenges. As people flow into cities, access to fundamental resources such as land, water, and energy is coming under heavy stress. City growth has put pressure on the land and on the provision of adequate housing, food, and transportation, with slums resulting from the huge relocation of people from rural to urban areas. Social problems such as unemployment, social exclusion, poverty, and inequality have increased in many cities worldwide. Improving governance and management in these urban enlarged and complex cities is frequently referred to as a main societal challenge for countries today (OECD, 2019).

Climate change is also impacting urban life. Over the last 50 years, the death of millions of people has resulted from climate change-related hazards and disasters. Weather, climate, and water hazards are considered responsible for 50% of all disasters, 45% of deaths, and 74% of global economic losses–which are largely affecting cities (WMO, 2021). Simultaneously, cities contribute to climate change, pollution, and environmental degradation. Cities growth is behind poor air and water quality, waste-disposal problems, and the destruction of natural ecosystems. Cities are large energy consumers, requiring an uninterrupted supply of energy estimated to account for 75% of global energy use today. Comprehensive urban planning practices that incorporate city green spaces, reduce energy consumption, and favor circular economy strategies are thus considered to be central for the development of cities in the future.

These urban challenges are enduring. International organisations emphasise that the speed of population growth will bring a variety of challenges: 3 billion people–around 40% of the world's population–will need access to adequate housing by 2030 (UN-Habitat, 2020b), while food and non-food agricultural production is expected to rise (FAO, 2018).

With regards to water, the expansion of cities is creating well-documented challenges both in the management of urban water resources and in the provision of urban water and sanitation services. Indeed, city growth, climate change, and urbanization have all impacted the natural water cycle, and cities, today, are at the centre of environmental disasters such as floods and tropical storms which pose great threats to the life and wellbeing of thousands of people and to the environment. The expansion of urban areas is creating difficulties in the provision of adequate drinking water and sanitation in many areas of the world, as well as making it difficult to manage the expansion and renewal of water networks in enlarged urban areas.

The character and implications of five major water challenges are considered in more detail below.

1. Flooding

Floods have caused some of the largest human and economic losses in the last 50 years (WMO, 2021). Floods might be caused due to proximity to coastal areas or rivers and/or the geology or topography of a particular city. In cases when an urban area has inadequate drainage (or no draining at all), urban flooding also occurs. Floods have enormous impacts on both individuals and communities, and have large social, economic, and environmental consequences. Damages from floods are not only direct and immediate, but they can also expand to supply chains and transport networks, affecting a city's future developments as well. Currently, nearly 20% of the world population are directly exposed to floods, and this annual flood damage to urban property alone amounts to over USD 120 billion annually, half of which is in North America (Sadoff, et al., 2015).

Indeed, many cities around the world have faced flooding in the past and are regularly on alert for flooding risks. Some of the cities facing episodes of severe flooding are Nagoya and Osaka (Japan), Miami, New York City, and New Orleans (USA), Gugzhou and Shenzhen (China), Paris (France), Ho Chi Minh City (Vietnam), Jakarta (Indonesia), and Manila (Philippines).

In this report, we see the case of Ningbo, a large coastal city in Eastern China that has experienced numerous events of flooding in the last 50 years. Ningbo has been ranked one of the top 20 global port cities most prone to flooding risk during the typhoon season, when tidal surges and intense rainfall are frequent. The risk of coastal flooding in Ningbo is expected to rise by 2050 because of population growth, urbanization expansion, and land subsidence. In the last decades, New York City (USA) has also been experiencing an increase in sewer overflows and floods caused by heavy rainfalls. This trend is expected to persist in the future, causing difficulties not only for the provision of water services to residents, but also damaging the coastal water bodies of the city.

2. Water scarcity

Water scarcity refers to the lack of access to adequate quantities of water for human and environmental uses (UNICEF, 2021). It is caused by natural phenomena, human influences, or a combination of both (i.e., physical water scarcity, drought), as well as because of a lack of suitable infrastructure to ensure access to the existing water resources (i.e., economic water scarcity).
Water scarcity causes severe restrictions and temporary interruptions to the water supply. This leads to higher operation and maintenance costs for industrial users and energy producers, income losses and competitive disadvantages in the agricultural sector, and losses in activities dependent on public water, like tourism (Spinoni, et al., 2016). It is estimated that droughts can limit a city's economic growth by 12% (Zaveri, et al., 2021). Water scarcity is currently affecting urban population: out of over 4 billion people living in urban areas, 143 million lack access to drinking water and 605 million are without access to at least basic sanitation facilities (WHO & UNICEF, 2019). It is expected that, by 2050, 685 million people, living in over 570 cities, will face an additional decline in freshwater availability of at least 10%. Water deficits are linked to 10% of the rise in global migration.

Evidence exists of water stress in cities such as Cape Town (South Africa), London (UK), Venice (Italy), São Paulo (Brazil), Bangalore (India), Cairo (Egypt), amongst many others. In some cities, such as Amman (Jordan), Cape Town (South Africa) and Melbourne (Australia), this decline in freshwater availability might be between 30 to 49%, while Santiago (Chile) may see a decline that exceeds 50% (UNESCO & UN-Water, 2020). This report provides two different examples of water scarcity. First, the Algarrobo (Spain) shows how the volume of water available in the local reservoir has halved in only a decade, going from 102 hm^3 in 2011, to 50 hm^3 in 2021. This change has put the agriculture and tourism-dependent local economy at risk. Second, Nakuru (Kenya), Africa's fastest-growing city and the fourth in the world, currently faces a daily demand of water of 70,000 m^3, while the available volume is 45,000 m^3. The demand for water is expected to rise significantly to reach 191,000 m^3/d in 2050 to serve the estimated population. These cases describe the difficulties that water scarcity is creating and the measures that have been proposed and implemented to try to deal with this challenge.

3. Deficient water quality

Water pollution, either point source or diffused, is causing inadequate water quality in many catchment areas around the world. Pesticides, fertilizers, salinization, chemicals, heavy metals, oils, etc., are some of the harmful substances reaching our water bodies. In cities, the lack of urban wastewater collection and treatment as well as the street runoff contaminants are pervasive problems. Pollution, at best, generates additional costs in ensuring access to safe water for the population. At worst, this circumstance means that water, not fit for purpose, is being distributed to water users and customers, transmitting diseases such as diarrhoea, cholera, dysentery, typhoid, and polio. Contaminated drinking water is estimated to cause 485,000 diarrhoeal deaths each year (WHO, 2019).

Many cities around the world including Pittsburgh (USA), Beijing (China), Mexico City (Mexico), Lagos (Nigeria), Caracas (Venezuela) have reported inadequate quality in their drinking water (World Resources Institute, 2018). In this report, we follow the measures that the city of Heredia, in Costa Rica, has put in place to deal with the deficient drinking water quality in the city. Heredia's water supply comes partly from surface waters with heavy sediment load, which makes human consumption difficult.

4. Aging or insufficient infrastructure

Problems such as infrastructure breakdown, failing pumps and motors, and water leaks are regularly reported across the world. Obsolete infrastructure is considered the cause of an average of 21% of water loss before distribution, threatening universal coverage of drinking water and sanitation and diminishing the capacity to protect citizens against water-related disasters. Significant investment is required to renovate and improve water infrastructure. This may include water supply networks, which on many occasions, are several decades old. According to OECD (2016), a total of 92% of surveyed cities (48 cities from OECD and non-OECD countries) have reported significant challenges in terms of updating and renewing these water infrastructures. Along with aging infrastructure, cities also suffer from inadequate water supply and sanitation infrastructure, unable to keep up with the population and urbanization growth. Globally, by 2050, the required investment for water supply and sanitation is

estimated at 6.7 trillion dollars. This bill can triple by 2030, considering the wider range of water-related infrastructure required (OECD, 2020b).

In this report, two examples of the challenges of an aging and insufficient infrastructure are presented. In Ciudad Juarez (Mexico), the authorities calculated that water leakage affected 47% of the total volume of water distributed. Mumbai (India), a megacity of over 8.5 million inhabitants, has approximately only 300,000 water meters. Such situations make it very difficult to provide accurate estimations of the populations' actual water needs, and to protect and manage the already strained local water resources. Details of the measures that the cities put in place are examined in further detail in the Annex.

5. Inadequate urban water planning

Beyond providing drinking water, sanitation services, dealing with aging infrastructures, cities also face problems due to poor planning practices. This challenge recognises that smart urban water management also fulfils other functions relating to environmental protection, health and well-being, social connection, emotional balance, and happiness. Adequate water infrastructure planning concerns more than just guaranteeing safe water services provision; it also regards the promotion and the conservation of water resources and the protection of urban ecosystems. Access to safe, open, and green water areas in cities (including coastal or waterfront spaces, fountains, parks, and green areas) promotes wellbeing and inclusion, as well as helps citizens to develop positive social interactions and healthy activities. These measures can also contribute to mitigating the impacts of floods and rising sea levels.

Busan, the second largest city in the Republic of Korea, aspires to adopt a friendlier urban design when it comes to access to water leisure and recreational area. The BEDC is a new development project planned to be built to the west of the city of Busan by 2028. One of the most distinctive challenges taken up by the authorities has been to facilitate public access to green and blue areas (parks, riverside, and wetlands) in the city, and to integrate nature into the other functions of the city – provision of commercial and business spaces, residential areas, and leisure and cultural zones. But improvements in the urban design of the cities can also be undertaken in existing cities via smart water solutions. Hong Kong (China) presents a very peculiar situation. Although it is an inherently water scarce city, water supply has been ensured thanks to an inter-basin transfer scheme bringing water into the city, which has resulted in an over-allocation of water for the city. A current smart metering pilot project is aiming to limit overuse of water and to promote its conservation.

Table 5 presents a comparison of the country cases reflected in the Annex that this report explores in detail. It is important to keep in mind that many of the city cases presented here face not only one, but several of the water challenges described. Water scarcity, insufficient infrastructure, and deficient water quality, for instance, are often simultaneously present. Table 5 highlights the challenge that the city has addressed more explicitly and directly, but any intervention on one of the challenges has an impact in the overall water status of a city.

Table 5. City Cases in the Report

City	Country	Region	Type of City			Type of Challenge Addressed
			Population	New or Existing Urban Development	Economic Development	
Algarrobo	Spain	Europe	Urban Settlements	Existing	High-Income Economy	Water Scarcity
Busan Eco Delta City	Republic of Korea	Asia & The Pacific	Medium Size	New	High-Income Economy	Inadequate Urban Water Planning
Ciudad Juarez	Mexico	North America	Medium Size	Existing	Upper Middle Income	Aging or Insufficient Infrastruc-ture
Heredia	Costa Rica	Latin America & The Caribbean	Urban Settlement	Existing	Upper Middle Income	Deficient Water Quality
Hong Kong	China	Asia & The Pacific	Large City	Existing	High-Income Economy	Inadequate Urban Water Planning
Mumbai	India	Asia & The Pacific	Megacity	Existing	Lower Middle Income	Aging or Insufficient Infrastruc-ture
Nakuru	Kenya	Africa	Small City	Existing	Lower Middle Income	Water Scarcity
New York City	USA	North America	Large City	Existing	High-Income Economy	Flood Risks
Ningbo	China	Asia & The Pacific	Large City	Existing	Upper Middle Income	Flood Risks

1.3. The global agenda for smart and sustainable development of cities

In the last 20 years, the international community has given particular attention to global urban water challenges. Several international agreements and guidelines have been adopted with the aim to coordinate an international response to these events. These agreements constitute a global agenda with a shared vision, goals and targets, and a plan for common action. Many of these international initiatives identify cities as central actors. Engaging with the city level has thus been considered crucial, and city authorities can follow international strategies while adjusting them to their local particularities. For this reason, many international agreements frequently establish objectives that require substantive progress at the city level.

The most comprehensive initiative touching upon urban water management has been the adoption of 2030 Agenda for Sustainable Development by the United Nations in 2015. The 2030 Agenda spells out the Sustainable Development Goals (SDGs), which is a collection of 17 interlinked global goals designed to be a "blueprint to achieve a better and more sustainable future for all" (UN, 2017). Agreed upon by governments around the world, the SDGs specify 169 targets in a wide range of areas, including poverty alleviation, economic growth, and environmental objectives. Two SDGs are particularly dedicated to water and to cities. They are Goal 6 and Goal 11:

- **Goal 6** aims to ensure availability and sustainable management of water and sanitation for all by the year 2030.
- **Goal 11** focuses on making cities inclusive, safe, resilient, and sustainable, by aiming to reduce the impact of disasters, reducing the environmental impact of cities, and by increasing the universal access to green and public spaces.

Figure 5. Sustainable Development Goals

To facilitate the implementation of the SDGs, other measures leading to their achievement have been adopted. With regards to goal 6, the UN declared 2018-2028 as the International Decade for Action "Water for Sustainable Development", a period when the UN family of organisations will carry out a series of actions to improve water sustainability and availability. Also, with the adoption of the UN 2030 strategy and the SDG 6 global acceleration framework, the UN has shown commitment for water action at the international level. Their

focus has been on accelerating progress towards the targets of SDG 6. These measures aim to provide support to monitoring and reporting at the global, regional, and sub-regional levels, to facilitate outreach and communication activities through publications and global campaigns, to provide technical advice, and to assist countries to identify top priorities.
SDG 11 has also received further attention. UN-Habitat has played a role in assisting national and local governments with the implementation of the city-related targets. With the adoption of the "Goal 11 - monitoring framework" and the UN-Habitat new urban agenda, endorsed by the UN General Assembly in 2016, the UN has argued that adequate urbanisation can help with attaining sustainable development targets. UN agencies have provided aid for the collection and analysis of urban data and assistance for the preparation of country-based reports.

Other key agreements concerning sustainable development have also given a central role to local urban action. The Paris Agreement, for one, is the landmark global agreement to combat climate change, and the Sendai Framework provides concrete actions for protecting development gains from the risk of disaster. Both these agreements indicate how crucial it is to engage citizens and urban authorities in taking action that limits runaway global warming and the impact of weather-related hazards at the local level. In fact, it is estimated that up to 65% of SDGs targets might be at risk if local urban stakeholders are not assigned a clear role in the implementation of the agenda (Kanuri et al., 2016).

Figure 6. Benefits of Smart Cities

Source: Woetzel et al. (2018)

To deal with these urban problems, the promotion of "smart" urban development has been considered a desirable objective, with smart technologies as central instruments for addressing and achieving solutions to urban challenges. The purpose of smart cities has been to improve policy efficiency, reduce waste and inconvenience, improve social and economic quality, and maximize social inclusion. The use of data and technology has been an influential global trend aiming to better decision-making at the city level. Data on the ICT access and

Hong Kong (China)

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usage (including access to computers, fixed and mobile internet broadband, use of the internet for professional, services and leisure, etc.), have shown a constant progression in all fields and socio-economic sectors across the world since the 1990s. The COVID-19 pandemic has recently accelerated these progressions. Taking steps to introduce ICTs has been one of the main strategies for meeting global challenges. We have witnessed initiatives for introducing smart technologies in sectoral policies such as transport, energy, education, natural resources management, and in the provision of many different services.

At the global level, international organizations have supported this trend to put smart cities at the forefront of a common global action. The "People-Centered Smart Cities Programme" is one of UN-Habitat's five global flagship strategic action programs. The program has emphasized how digital technologies can help to reach SDGs by improving livelihoods, economic, and gender equity, while at the same time recognizing the many challenges that ICTs themselves pose. For this reason, UN-Habitat has made efforts to enable the establishment of long-term partnerships with national and local governments and other stakeholders to facilitate an appropriate transition towards a wider use of smart technologies.

The United Nation has also spearheaded an initiative entitled, United 4 Smart Sustainable Cities (U4SSC) with the participation of the International Telecommunication Union (ITU), the United Nations Economic Commission For Europe (UNECE) and UN-Habitat, launched in May 2016. This initiative aims to provide cities with the criteria and the means to evaluate their contributions in making cities smarter and more sustainable.

Overall, these initiatives show that smart urban development has been at the top of the global agenda for international organizations. However, while international agreements provide guidance, the responsibility for defining and executing these measures, policies, and treaty goals lie within each UN member state. The next chapter examines some of smart water initiatives that have been implemented in different countries in the Americas, Europe, Africa, and Asia. These case studies help to identify the main features of a Smart Water City and show how ambitious actions in cities are critical to meeting global targets.

CHAPTER 2
SMART WATER CITIES

2.1. Functions of water in cities

Meeting the basic need for safe drinking water and sanitation has been the key objective in water resources management at the city scale. Drinking water and sanitation have been services traditionally provided by local water services suppliers, either public or private. Ensuring that these essential demands for water services are met has been a condition for societal well-being and socio-economic development. Therefore, water planning authorities have put the provision of urban water services at the centre of development plans.

In addition to meeting these basic needs, water serves other equally important functions, as well, and these can best be understood by examining the concept of "water cycle". The water cycle refers to the constant movement of water in Earth's atmosphere. This process takes place through five different stages (condensation, precipitation, infiltration, runoff, and evapotranspiration) over four spheres (atmosphere, lithosphere, hydrosphere, and biosphere) and in three different forms (liquid, solid (ice), and vapor). The water cycle is frequently illustrated with a model representing the circulation of water in the watershed – see Figure 7.

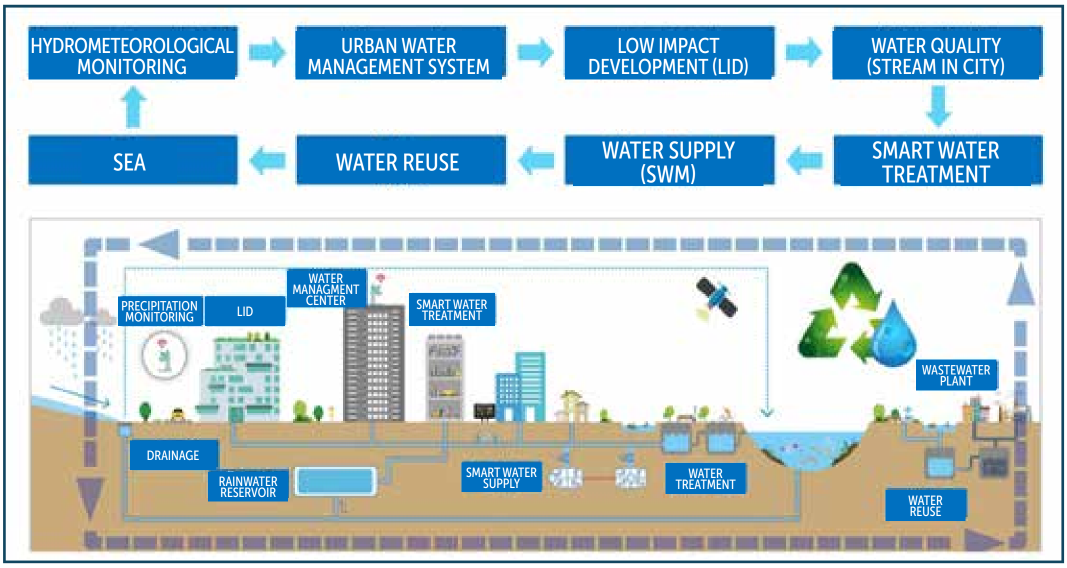
Figure 7. The Water Cycle

At each stage of the water cycle, water fulfils important functions: it regulates the temperature of its surroundings; it erodes rocks and converts them into soil; it produces minerals that then circulate in the different spheres; and it transforms and creates geographical features, etc. In short, water does not only serve human needs, but it also modifies the environment and creates the conditions for human, animal, and plant life, as well as for ecosystems to survive. Significantly, the water cycle also represents the idea that any prospective intervention at any stage of the water cycle can have an impact in all subsequent stages.

Human activity has changed and disrupted the water cycle: irrigation, abstractions, storage, deforestation, desalination, etc. are all common human activities with implications in how water continues to circulate through the different phases of the water cycle. Cities above all have altered the water cycle in such a way that experts propose to use the term “urban water cycle” as a distinct and differentiated concept to the natural water cycle (Marsalek, et al., 2008).

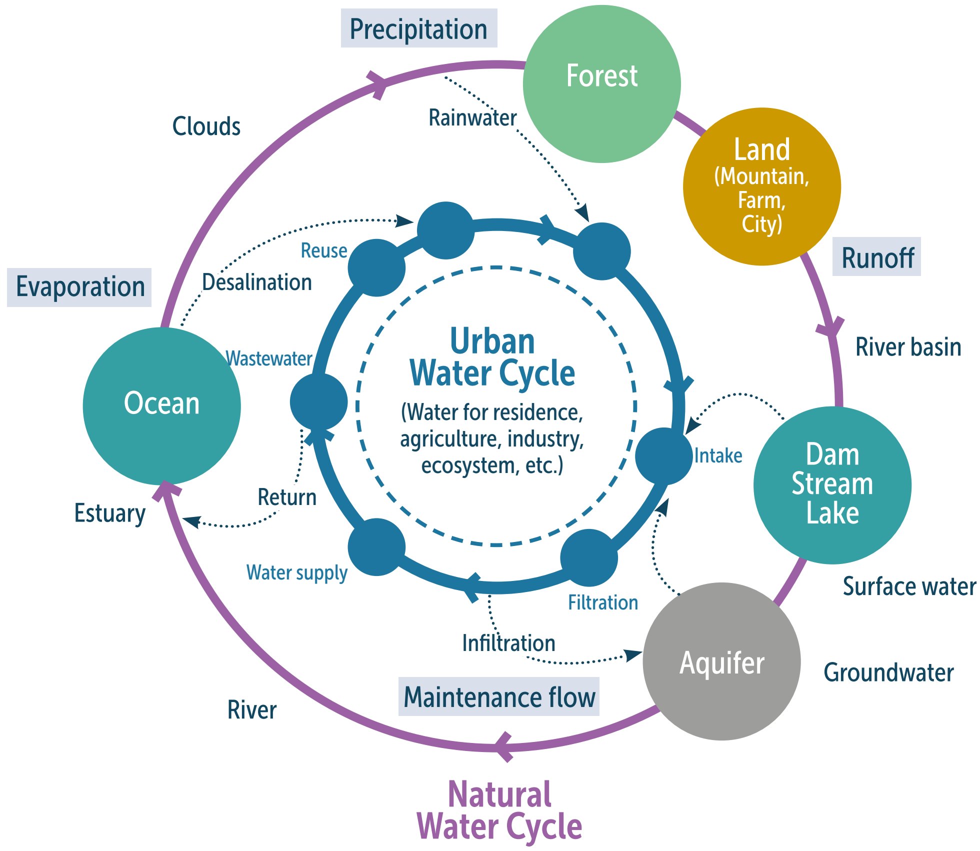
In urban settings, the principal structure of the water cycle remains the same, but certain key aspects have changed because of phenomena such as urbanization, industrialization, and population growth. Human activities destined to treat water resources and bring them to human-acceptable standards have changed water’s journey from catchments through reservoirs and treatment to domestic taps, and from households to nature. Concrete and pavements found in cities limit water infiltration and create run-offs, which have brought pollution and waste into storm water systems as well as have limited the replenishment of groundwater aquifers. These have consequences on the water available for abstraction. In short, human intervention has modified water circulation at the city level, altering the quality and the availability of water resources– See Figure 8.

Figure 8. The Urban Water Cycle



An understanding of the different functions of water needs to be at the core of any smart and integrated urban planning project. Indeed, awareness of what water does at different stages of its water cycle, and what effects cities have on water resources and the environment, can help to plan cities in a more integrated, effective, and sustainable manner. Smart water technologies have a role to play in providing improved water services to city inhabitants, but they are also called on to improve urban planning practices by enhancing urban ecosystem's resilience and aiding in human coexistence with nature. Smart water technologies are tools that can help manage water resources more efficiently and sustainably, facilitating that water also fulfils other key functions beyond the (critical and indispensable) supply of safe drinking water and sanitation in a city. Such understanding is essential for the development of Smart Water Cities.

Figure 9. The Natural and Urban Water Cycles



2.2. What is a Smart Water City?

To examine the concept of "Smart Water City," it is necessary first to examine what a "smart city" means. The concept of "smart city" has become a promising aspiration to deal with the challenges that world cities face nowadays. The term refers to improving the quality of life via the use of ICTs in different sectors of the urban environment (including water, transport, energy, education, etc.). The origin of the concept goes back to the 1980s, to the initial development of computers and robotics, the expansion of the internet, the formation of large technological companies,s and new industrial clusters such as Silicon Valley. The 'smart city' concept appeals to views about highly engineered and competitive cities (Glasmeier & Christopherson, 2015).

Different definitions and criteria for identifying the main features of a smart city exist (For a discussion on the "smart city" concept, see Ahvenniemi, et al., 2017; Albino, et al., 2015). The United Nation has defined a smart city as "an innovative city that uses ICTs and other means to improve quality of life, efficiency of urban operation and services, and competitiveness–while also ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects" (UNECE, 2015). For this approach, the use of ICTs is inextricably linked to the impact of such technology. A smart city is not only a city that implements ICTs, but is one that reports substantial and measurable improvements in the urban sustainability and the quality of life of local actors because of the implementation of these technologies. Thus, smart interventions pay careful attention to the target population whose needs are being addressed, the circumstances of where the intervention is proposed, as well as impact to future generations and the environment. This understanding goes beyond characterizing a smart city as a city that exclusively employs technologies in the provision of services to its citizens (be it transport, communications, infrastructure, logistic, or energy systems, or all of them combined). It also concerns the impact of the use of ICTs in everyday urban life. A smart city pays attention to, for instance, the number and uptake of technologies by citizens and organizations or the length and strength of the ICTs network, as well as the social and the environmental consequences of their use.

For the definition of "Smart Water Cities" the present report builds, along with the UN's definition of a smart city, on the "Smart Water Management - Case Study Report" edited by IWRA and K-water. This report examined the use of integrated, real-time information and ICTs solutions, such as sensors, monitors, Geographic Information System (GIS), satellite mapping, and other contactless, intelligent tools in both urban and agriculture water management. The report presents evidence of how SWM has provided solutions at different scales and across various urban and rural contexts, and how they have impacted the social, economic, environmental, governance, and technological spheres. It provided evidence of how SWM projects can aid in the achievement of the SDGs by improving livelihoods and economic and gender equities, reducing hunger, broadening access to knowledge and education, enhancing health and wellbeing, adapting to climate change, and improving safety. In addition, the report also argued for establishing an adequate governance and regulatory framework to support the implementation of smart and sustainable water projects and initiatives.

With this understanding, a Smart Water City is defined to include the use of ICTs in urban water management and the impacts of those ICTs on the quality of life of citizens–including socio-economic, cultural, and environmental aspects. In this sense, the definition combines the use of smart technologies with the results of their use, which concerns not only a city's technological prowess, but also wider aspects of economic efficiency, social equity, and environmental sustainability. In addition, the definition stresses the importance of adequate water management for the development of cities. Smart Water Cities develop thanks to a supportive institutional, regulatory, and policy framework.

Furthermore, in a Smart Water City, ICT-based intelligent technologies complement and improve existing infrastructure and technologies for water management within the whole urban system. They are a supportive tool for the different functions of water in urban settings. This understanding highlights that Smart Water Cities concern not only the provision of drinking water and sanitation services for urban water users, but also other urban water functions such as urban water restoration, waterfront usage, and integrated water managements (see Box 3).

Box 3. Definition of a Smart Water City

"A Smart Water City is a sustainable city with contactless, intelligent water management for all"

A Smart Water City improves the quality of life of citizens by solving existing urban water problems based on various technologies and ICT technologies throughout the urban water cycle. It provides not only individual solutions for conventional water management, such as drainage, water treatment, and wastewater treatment. It also improves comprehensive water management through the restoration of urban water cycle, waterfront usage, and intelligent water management.

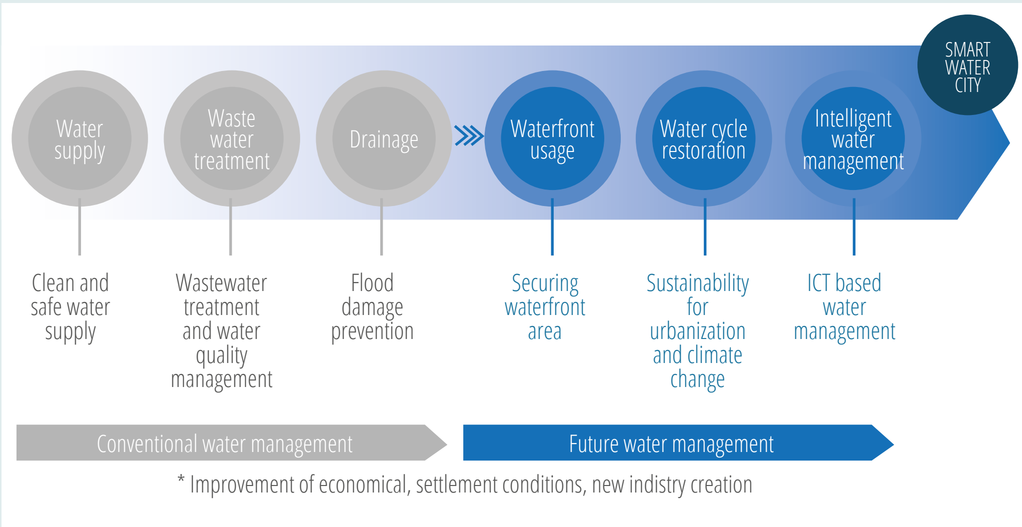


Figure 10. Components of a Smart Sustainable Water City

2.3. National and local policies and strategies for Smart Water Cities today

This section examines some of the national and regional policies and strategies put in place in the nine case study cities presented in the Annex of this report. These cases demonstrate attempts to implement smart water solutions and the Annex provides illustrations of the regulatory measures, the national plans, the economic instruments, and the voluntary means, etc., adopted in different cities to limit the need for new water resources and to optimize the available ones in different places around the world. The cases show that, in addition to having the knowledge and capacity to develop and implement technical solutions to urban water challenges, policies and strategies need to be in place to enable the adoption of smart water solutions. Having an appropriate regulatory framework is a requisite for adopting initiatives conducive to sustainability and smart development. Adequate economic resources are also crucial for the economic viability of the smart initiatives. Developing appropriate administrative capacity is also crucial for making decisions concerning water resources. In this sense, developing Smart Water Cities does not only depend on having the adequate technology in place, but also on removing non-technical obstacles and putting in place policy measures to enable their adoption.

Algarrobo (Spain)

The case of Algarrobo, in Spain, presents a successful smart city local initiative led by a private company within a facilitating national and regional regulatory framework. The case study looks at the implementation of smart water technology for the treatment and reuse of reclaimed urban waters in an area where finding alternative sources of water is of high strategic value. In this sense, the Spanish case shows the importance of establishing a regulatory framework where local initiatives can prosper. Such framework, although not dealing directly with the development of smart water technologies, has facilitated the adoption of innovative practices for water reuse and wastewater treatment initiatives. It has reduced potential obstacles that this initiative could have otherwise found. In particular, the case of Albarrobo shows a close alignment between European, national, regional, and local strategies to favor the introduction of innovative solutions for water reuse.

At the European level, the Water Framework Directive (Directive 2000/60/CE) establishes that all water bodies in the EU must achieve good qualitative and quantitative status–measured with a series of pollutant limits–while the

Urban Wastewater Directive (Directive 91/271/EEC) sets the obligation to treat wastewater “whenever appropriate”. More recently, Regulation 2020/741 has established a series of minimum requirements for the reuse of water, which supports the implementation of initiatives for the safe reclaim and reuse of wastewater throughout the EU.

To meet these EU requirements, the Spanish government adopted the National Plan for the Reuse of Reclaimed Water. This plan aims to achieve “zero discharge” into coastal areas by providing incentives for the use of reclaimed water in inland areas and promoting good practices. The Spanish Circular Economy Strategy joined these efforts and proposed a complimentary goal of achieving a 10% improvement in the efficiency in the use of water, and in the Circular Economy Action Plan 2021-2023, where water reuse is considered a priority area. For its part, the regional level has adopted initiatives aiming to deal with the region’s water scarcity while simultaneously facilitating access to water for irrigation–one of the pillars of the regional economy. Different regional policy strategic plans, such as the Andalusian Pact for Wate, the Andalusian Circular Bioeconomy Strategy, and the Andalusian Climate Change Law, seek to widen the use reclaimed water and to implement innovative agricultural techniques that are better adapted to climate change, more efficient in the use of water and energy, and which depend less on the use of fertilizers.

Busan Eco Delta City (Republic of Korea)
Korea was the first country in the world to enact legislation on smart cities, beginning in 2008. While the project to develop the BEDC date of 2012, the origins can be traced to 2008 when Korea has been the first country in the world to enact legislation on smart cities. After the adoption of the Act on the Construction, etc. of Ubiquitous Cities (U-City Act) in 2008, the Act on the Promotion of Smart City Development and Industry (Smart City Act) was incorporated in 2017, showcasing 34 amendments to the original act. The Smart City Act defines a smart city as ‘a sustainable city wherein various city services are provided based on city infrastructure constructed by converging and integrating construction technologies, ICTs, etc. to enhance its competitiveness and liveability’) (Article 2, Paragraph 1). With this Act, smart cities in Korea are considered a “platform to improve the quality of life for citizens, enhance the sustainability of cities, and foster new industries by utilizing innovative technologies of the 4th Industrial Revolution (4IR) era” .

The scope of actions for the smart cities in Korea has evolved continuously. In the early 2000s, only ICT-based infrastructure projects in new town developments were considered smart city projects (see Table 6). ICTs were seen as a main driving force of economic growth. Installing communication networks and Integrated Operation Control Centers (IOCCs) for data was led by the Ministry of Land, Infrastructure, and Transport (MOLIT). Later, the perspective on smart cities was expanded to integrate existing infrastructure and services, and smart city projects were implemented in existing cities as well as in new towns. The central government was still the main facilitator of these projects, but more ministries other than the MOLIT were involved in development, such as the Ministry of Science and ICT (MSIT) and the Ministry of Trade, Industry, and Energy (MOTIE).

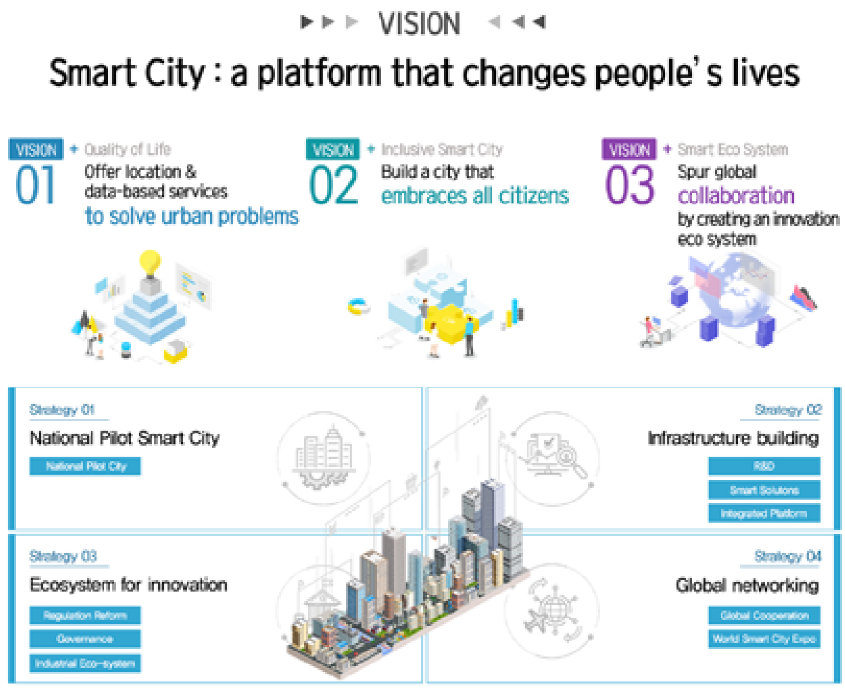
Table 6. Smart City Development in the Republic of Korea

Stage	Construction stage (2003-2013)	Connecting stage (2014-2016)	Enhancement stage (2017-present)
Goal	To create new growth engine by combining ICT with construction industry	To provide high quality service by integrating existing infrastructure and service	To solve urban problems and create innovative jobs
Information	Vertical information integration	Horizontal information integration	Cloud based information integration
Platform	Closed platform	Public platform (open to relevant organizations)	Open platform (open to private sectors)
Legal framework	Act on the Construction, etc. of Ubiquitous Cities	Act on the Construction, etc. of Ubiquitous Cities	Act on the Promotion of Smart City Development and Industry
Main agent	MOLIT	MOLIT, MSIT, MOTIE	Smart city governance
Target	New towns	New towns, existing cities	New towns, existing cities, declining cities
Projects	Integrated Operation Control Centers, physical infrastructure	Smart city platform, service integration	National smart city pilot projects, smart city platform, smart city R&D, smart city Challenge (for existing cities), smart urban regeneration (for declining cities)
Resource	Profits from residential district development projects	Government budget	Government budget, resource from private sectors

Source : OECD, 2020a.

More recently, with the adoption of the Smart City Act in 2017, the paradigm on smart cities has shifted once again. While the earlier U-City Act was more interested in the smart city construction, the latter Smart City Act brought more attention to smart city promotion and to tackling urban challenges and creating and fostering smart city-based ecosystems. Accordingly, the central government has encouraged local governments and the private sector to engage with smart city projects. It has also provided active policy support such as through financial investment and regulatory facilities. Consequently, as of 2019, 78 local governments now run dedicated organizations for smart cities, and 67 local governments are participating in the central government-supported smart city projects (MOLIT, 2019). The 3rd Smart City Comprehensive Plan (2019-2023) has been adopted which provides medium and long-term roadmaps for smart cities that aspire to change citizens' lives with better quality, more inclusive, and smarter cities (see Figure 11).

Figure 11. The 3rd Smart City Comprehensive Plan (2019-2023) in the Republic of Korea



Source: MOLIT (2019)

One of the pillars of the 3rd Smart City Comprehensive Plan is the National Pilot Smart City strategy, announced by the Presidential Committee in 2018 on the 4th Industrial Revolution (PCFIR). This strategy involves building two new towns in the cities of Sejong and Busan to serve as a test bed for smart city technologies, including 5G, AI, blockchain, etc. (See Table 7). BEDC is to focus on smart water resources and smart water service provision, thus becoming an environmentally friendly waterside city that introduces smart technologies capable of meeting and improving urban performance on the water sector. BEDC will feature new technologies such as smart water supply, hydrothermal energy, and eco-filtering. In addition, the BEDC is to provide a smart city technology "sandbox," supporting the increased development of start-ups and job creation in new growth industries.

Table 7. Overview of the National Pilot Smart City in the Republic of Korea

National Pilot Smart City	Sejong 5-1 Living Area	Busan Eco Delta Smart City
Location	In Sejong Special Self-Governing City	In Busan Metropolitan City
Area (km^2)	2.7	2.8
Population	22,500	8,500
Innovation area	Mobility Healthcare Education Energy Governance Culture Job	Robot Learn, work and play Smart intelligence **Water** Energy Education & living Healthcare Mobility Safety Park

Source: MOLIT (2019).

The BEDC is a case study where political authorities have been explicit about their objectives to develop comprehensive smart water initiatives for dealing with water challenges. In this case, efforts and resources have been mobilized at the national level to plan and implement full Smart Water Cities.

Ciudad Juarez (Mexico)
Ciudad Juarez is a city situated in the state of Chihuahua (Mexico), in an area facing a critical problem of overexploitation of aquifers in a semi-desert environment. An increase in the demand of water for both urban and agricultural use is putting water access at risk for today's and for future generations. Conscious of this problem, the Chihuahuan government launched an open consultation procedure in 2016 to discuss a common water strategy for the state which would deal with topics such as the overexploitation of aquifers, coverage of drinking water service, water quality, treatment and reuse of treated water, climate change, rainwater management, governance, climate change, and agricultural water consumption.

Based on the above, the State Water Plan 2040 (PEH 2040) was prepared in the state of Chihuahua. It was an unprecedented and unique effort in Mexico, which included six objectives for sustainable use of water in the next 25 years. Such aims include to:

- guarantee the water security of the state of Chihuahua;
- encourage the rational use of water in agriculture;
- strengthen the utilities;
- encourage governance and governance in the water sector;
- reduce the risk of meteorological phenomena to the population; and
- promote education, research, and innovation in water issues.

These 6 objectives include 8 strategic projects and 654 specific actions, requiring a total investment of 69,707 million pesos (3,485 million USD) for the period of 2019 to 2040. Among these strategic projects is the introduction of intelligent measurement and pressure management devices. Included in the Annex is the case of Ciudad Juarez, an example of how smart water initiatives develops as a tool within a larger policy framework that looks comprehensively at water challenges.

Heredia (Costa Rica)
The case of Heredia is similar to that of Algarrobo in Spain. It shows how the national regulatory framework has put in place smart urban initiatives to meet the standards and requirements of its legal water framework. The country has adopted a National Drinking Water Policy for the period, 2017-2030. One of the guidelines is the rational use of drinking water. It states that water sources must be supplied efficiently, using appropriate infrastructure and technologies to ensure their sustainable use. Likewise, the current national water policy from 2009 also presents strategic guidelines for water bodies to maintain their potential supply. In addition, the 2008 National Plan for the Comprehensive Management of Water Resources, which is still in force, works to promote efficient water use, as expressed most recently in the drafted National Drinking Water Policy as one of its guiding principles. Both the national water policy and the national plan for integrated water resources management are in the process of being updated.

However, even though current policy and planning instruments recognize the importance of adequate infrastructure and technologies, this is not reflected in specific incentives for the development and implementation of innovative technological solutions in Costa Rica. Some efforts to create incentive mechanisms for the management of watersheds have been established, allowing drinking water operators and other entities involved in water resource management to have access to the financial resources necessary for implementing these innovative technologies; however, improvements are needed to ensure that smart water technologies are more widely implemented.

Hong Kong (China)

As one of the two Special Administrative Regions established by China's central government in the late 1990s, Hong Kong is promised a high degree of autonomy under the "One-Country, Two-Systems" framework. Since 1997, Hong Kong develops its own policy approach to managing a range of social, political, economic, and environmental policy matters, including those pertaining to urban water resources management. Thus, unlike the rest of the country where local authorities would take cues from national policy frameworks in formulating their respective local-level regulatory measures, Hong Kong is given a relatively free hand to conjure its own strategy, policies, and programs for managing its water resources.

The first formal decision to apply smart technologies to managing the city's urban infrastructure and amenities could be traced to the promulgation of the "Smart City Blueprint for Hong Kong" in 2017. According to this Blueprint, 76 initiatives were launched, under six policy areas, to address the challenges of city management and improve people's livelihood through innovation and technology ("Smart Mobility", "Smart Living", "Smart Environment", "Smart People", "Smart Government", and "Smart Economy"). Officially, as pointed out by Hong Kong's Chief Executive's in her 2020 Policy Address, "smart city development aims at allowing the general public to better perceive the benefits of smart city and I&T in their daily lives". In late 2020, the Hong Kong Government released the Smart City Blueprint for Hong Kong 2.0, which contained more than 130 smart city initiatives.

The application of smart technologies for managing urban water resources is exemplified by Hong Kong's water agency—the Water Supplies Department (WSD)—to build a Water Intelligent Network (WIN) to reduce leakages from its water distribution network. To help it tackle the problem of water loss and the impact to its water supply network, the WSD, since the mid-2010s, has been configuring its 8,000 km-long water pipes into 2,400 District Metering Areas (DMAs) for monitoring and detecting leaks. The implementation of WIN could help WSD to identify DMAs that are showing higher degrees of anomalies in their flow rate data and thus, need to be given a higher priority in receiving follow-up actions such as repair, rehabilitation, or replacement.

Mumbai (India)

Applications of smart water technologies in Mumbai can be traced back to the early 2000s. The Sujal Mumbai Abhiyan program (2007) and the Automated Meter Reading (AMR) project in 2009 are two important locally-

led initiatives that intended to map Mumbai's water infrastructure and to implement measures such as water supply augmentation, alternative sources, leak prevention, water recycling, management, and citizen participation, respectively (Desai & Raj, 2012).
More recently, however, India has witnessed a top-down push for smart city development through the evolution of national level schemes aimed at urban development. The Jawaharlal Nehru National Urban Renewal mission (JNNURM) and the subsequent 5-year Smart cities mission (SCM)–both implemented through the Ministry of Housing and Urban Affairs–have played a major role in promoting and funding the development of smart cities. The JNNURM has targeted the rejuvenation of cities and towns across India between 2005 and 2015 (Ministry of Housing and Urban Affairs, 2021) and promoted the use of IT in projects which included water supply and sewerage (Sethi, 2012). These initiatives concerned greenfield cities exclusively, and aimed to attract foreign investments, technology firms, and private real estate companies (Roy, 2016; Prasad & Alizadeh, 2020). The SCM reframed the concept of Smart Water Cities to include, as well as greenfield, brownfield and pan city development projects. It aimed to help establish a total of 100 smart cities and towns in India. These projects would be co-funded by governments at different levels as well as external funding from financial intermediaries, multilateral organizations, private sector, etc. (Aijaz, 2021). The projected smart cities have sought to integrate technology in a more efficient way to create liveable, inclusive and sustainable cities (Aijaz, 2021; Prasad & Alizadeh, 2020).

However, the implementation of these plans has been inadequate for various reasons. As the Mumbai case study shows, lack of participatory planning, deficient coordination between citizens and government, and inadequate monitoring mechanisms have been present. Recent assessments of the SCM show that only 50% of the project has been completed which can be linked to the difficulties of states and union governments to mobilize necessary funds (Aijaz, 2021). Cost recovery through service charges has been opposed for fears of inequitable development (Aijaz, 2021; Housing and Land Rights Network, 2018). Concerns about the sustainability of these projects have been raised (Roy, 2016; Prasad & Alizadeh, 2020). Local politics has also influenced the implementation of these national plans, as local authorities have resisted what they perceived to be an erosion of municipal authorities' powers (Aijaz, 2021). The Mumbai case shows that the successful implementation of water ICTs requires more than technological prowess; it requires an adequate institutional and decision-making framework.

Nakuru (Kenya)
The Nakuru case study presents an initiative to address both floods and water scarcity, via the adoption of a sponge city project. The case shows how urban water policies are strongly connected to other local initiatives – in this case, urban planning and land use policies. Thus, successful implementation of measures to deal water challenges is strongly connected to and, at times, dependent of, a different set of local initiatives, institutions, and actors. The water system is interconnected to other areas that might influence the success or failure of water sector initiatives.

The case study follows the development of a water policy initiative in the rapidly growing city of Nakuru (Kenya). Population growth is causing the expansion of city-slums, increase in water demand, and difficulties to supply water to 100% of the residents in these cities. To deal with the challenges of population growth, the Kenyan government has adopted the national strategy, 'Vision 2030' (The Ministry of Planning and Devolution, 2007), which has prioritized management of urbanized areas as one of the development strategies in the country. Vision 2030 aims to enhance the provision of high quality of life for all citizens in a clean and well secure environment, including access to adequate water resources. Deriving from this strategic plan, the government has aimed at facilitating and enhancing sustainable urban development through the adoption of an Integrated Urban and Regional Planning Management Framework of the towns/cities. In addition, the National Urban Development Policy (NUDP) and the National Land policy both aim to enhance sustainable urban planning and management of natural resources through governance and delivery of accessible, quality, and efficient infrastructure and services. The Urban Areas and Cities Act has sought to provide different criteria on development and to establish urban areas that make use of social inclusion of its residents. The Integrated Urban Areas and City Development Planning Management Framework has emphasized ensuring quality delivery of various services such as water provision, solid waste management, and good health of its residents (Government of Kenya, 2012). The Kenya National Adaptation Plan (NAP) 2015-2030 and the National Climate Change Action Plan 2018 to 2022 looks at urban adaptation strategies and innovations for climate change including control of flooding and promotion of green infrastructures (Republic of Kenya, 2016). Addressing the challenges of water resources management in the country has been considered not in isolation but in connection with larger land development and urban management policies.

The actual implementation of these policies has been, however, deficient, and has negatively impacted the success of water initiatives like the Nakuru Sponge City Project. Poor urban planning practices and poor environmental management make it difficult to provide adequate water services to the population. Limited technical and institutional capacity within the various departments and ministries in sustainable urban planning and a reduced number of stakeholders/actors engaged in implementation and management of sustainable urban development have also contributed to these difficulties.

New York City (United States)

The New York City case study illustrates how the implementation of smart water technologies has complemented other policy measures to meet the city's objectives for water resources management. Indeed, the local water policy makers have seen water ICTs as tools along with other policy options, such as the construction and upgrade of green and grey water infrastructures and improving the existing pollution control strategies.

In the United States, the Clean Water Act (CWA) establishes the basic structure for regulating discharges of pollutants into waters and regulating quality standards for surface waters. In 2010, with the adoption of the Green Infrastructure Plan, New York City developed a detailed framework and implementation plan to meet the twin goals of better water quality in New York Harbour (in line with the CWA standards) and a liveable and sustainable New York City.

The plan identified source control and the development of integrated green infrastructure as central strategies to ensuring compliance with the CWA. This plan led to the launch of the New York City Green Infrastructure Program, which has implemented over 10,000 green infrastructure practices and managed over 1,200 "greened acres" constructed or currently in construction at the time of this report. Over the last several decades, the city has invested more than 45 billion USD in the construction and upgrade of critical wastewater and drainage infrastructure. In recent years, the city has committed an additional 10.6 billion USD investment in environmental protection for its water bodies. Smart water technologies have been employed in several projects, as indicated in the Annex, with the purpose of providing more accurate information on water status, i.e. water quantity and water quality. These initiatives have served to complement existing approaches that control pollution, drainage, and flood risks.

Changing climate, population growth, aging infrastructure, limited resources, and increasingly complex water quality issues have led the New York City authorities to new approaches for achieving legal and policy requirements. New York City has been actively engaging with other cities that have experienced extreme rain events to exchange knowledge and develop innovative solutions to prepare for more and heavier downpours, or cloudbursts, brought about by climate change. At its core, the city continues to seek solutions that integrate watershed, water resources, and water facilities management in a more holistic manner. The use of water ICTs is considered a complementary approach to this vision.

Ningbo (China)

Ningbo, a city situated in Eastern China, suffers from flood risks. The Chinese have chosen to develop pilot cities in Ningbo to test smart water technologies and SWM practices, to boost and support the modernization of water infrastructures, and to control flooding. These technologies include the use of remote sensing, big data, and 5G. Ningbo is also testing SWM practices to improve coordination, service efficiency, and for other innovative work practices. The Ministry of Water Resources, in charge of the implementation and operation of water ICTs in the pilot cities, has established the principles that rule over the Smart Water City plans. They include:

1. Evidence-based, problem-oriented planning. Smart city plans analyse status, detect resources and data needs, identify challenges and obstacles to defining and achieving realistic and feasible goals, and to prioritize which obstacles to address first.
2. Innovation and Creativity. Smart city plans promote the innovative application and integrative use of new technologies, such as Internet of Things, remote sensing, big data, artificial intelligence, 5G, blockchain, and more.
3. Cooperation and data sharing. Smart city facilitate relevant real-time information on infrastructure and shares resources with all relevant actors.
4. Evaluation, replication and upscaling. The Ministry of Water Resource is keen to evaluate the results of these initiatives and examine what positive outcomes can be up-scaled and replicated nationwide to achieve efficient and beneficial development of SWM in China.

Overall, the cases show two different national and local policy approaches to the implementation of innovative water technologies. BEDC and Ningbo have been pilot projects supported by the national governments. Their developments have served to test innovative water technologies as well as potential solutions, and to learn from them in order to apply them in other places and circumstances. In all other case studies, technologies have been employed, with more or less success, to reach policy objectives regarding the environment, water services provision, and/or urban planning. In these cases, water ICTs have been considered a vital tool for fulfilling local objectives. The cases in the Annex demonstrate this, illustrating several factors that have impacted facilitation or adoption, be it an adequate institutional framework, economic resources, appropriate administrative capacities, etc. This shows that the successful implementation of smart water technologies goes beyond technological knowledge and capacities.

2.4. Smart water technologies in world cities today

Smart technologies are developing rapidly around the world, providing an evolving group of innovative and integrated solutions for urban challenges. They are creating a new area of development for a new industry with large economic incentives and opportunities for growth. Some estimates refer to a global market potential of 651.7 billion USD for the smart city market by 2028 (Adroit Market Research, 2022).

In the water sector, ICTs uptake has been slower than in other sectors, but policy makers and the industry are paying close attention to smart technologies for both water resources management and water services provision (Leflaive, et al, 2020). Devices such as smart pipes and sensor networks that detect and measure water strain, temperature, and pressure anomalies, as well as smart meters to measure consumption, membranes, and cloud computing to share information, and smart materials that improve water infrastructure and mechanisms, etc., are among the devices designed and manufactured to help deal with urban water challenges. With demands for water projected to grow dramatically –up to 1% per year in all sectors (UNESCO & UN-Water, 2020)– these advanced technologies play a vital role: they can provide real-time, automated data on water quality, water use, and its consumption, as well as the functioning of the infrastructure, etc., which could contribute enormously to resolving pressing water challenges linked to climate change and demographic shifts.

Some key technologies have been put in place to improve the quantity and quality of water resources available in cities, to manage urban water risks and their potential impact, and to enhance water urban services provision. The Annex details several city case studies which highlight these technologies and which provide evidence of how ICTs are helping water service providers deal with urban water challenges, whether they are floods, water scarcity, deficient water quality, aging infrastructure, and/or inadequate urban planning. Smart solutions are contributing to more efficient management of water resources.

Indeed, water technologies have been used to improve the response to climate change and extreme weather events in cities. With flooding risks, sophisticated equipment has been put in place to monitor the status of water bodies and to provide warnings about rapid changes in storage, and to communicate this information in real time. This technology allows water authorities, as well as citizens and organizations, to have the most up-to-date information and to prepare for any potential water disaster. This pioneer technology has been put in place in the pilot project of the city of Ningbo (China), which faces large flood risks. The local government has adopted a plan to introduce innovative smart water technology to monitor water levels and produce a warning system that allows the authorities prepare in advance against floods. In New York City (USA), the department in charge of environmental protection has led a series of interventions that work to limit the volume of stormwater entering the city's sewer system. These interventions include plans to introduce green infrastructures, public and private properties retrofits, and new pilot drainage systems. ICTs have also been extensively employed in the city planning and urban expansion to restore the natural water cycle. Together, these integrated water management initiatives strive to ensure that the city can manage large volumes of water in future storms and flooding events, limiting their potential damage.

ICTs have also been employed to confront water scarcity. Smart metering has been a key ICT strategy to limit water misuse in many cities around the world. It is estimated water metering can achieve reductions of approximately 15% in higher-income cities. In developing cities, where baseline residential consumption is lower to begin with, savings are more modest but also considerable (Woerzel et al., 2018). The objective of the installation of smart meters has been to track water consumption and to give fast and reliable digital feedback messages to the water service provider and/or the consumer on the amount of water employed. Water tracking has helped to detect water losses, increase awareness on water consumption, and nudge people toward water saving measures. Ciudad Juarez in Mexico, Mumbai in India, and Hong Kong in China are cities that have introduced smart metering. The technology employed has been different, but the objectives have been similar in that they aim to reduce water consumption and save water. Water metering in these two cases has also been particularly useful for identifying problems in aging

infrastructure, as it has helped to find leakages and detect low or irregular pump pressure, thus optimising the repair and replacement of old infrastructure and prompting action when incidents have been identified.
To deal with water shortages, some cities have also developed the means to increase water storage, retention, and recharge, to supply water for domestic and industrial uses at times of needs. In the Annex, we can see the case of Nakuru (Kenya), where a project to harvests excess water and to enable water storage for periods of drought has been planned. Nakuru shows how ICTs have been employed to involve residents in decision-making processes to map out problems and propose solutions.

Smart technologies are also employed to reduce the need for new fresh water supplies by using reclaimed water (wastewater/grey water) for meeting local water demands. A growing recognition of the value of this resource is broadening the scope of its application: urban and peri-urban agriculture, irrigation of golf courses, parks, residential properties, highway medians and other landscaped areas, toilet flushing, car washing, etc. A good case for this is in the municipality of Algarrobo (Spain), where smart technologies have been adopted to reclaim urban wastewater for agriculture irrigation and fertilization. The implementation of this technology has had a positive environmental impact by reducing the demands on already stretched local water bodies, promoting local economies, and facilitating job creation.

Water technologies have been used to improve deficient water quality. In many countries, devices such as automated sensors have been used extensively in pollution sampling points across freshwater and drinking water sources to monitor, collect, and share information about the status of water. These ICTs have served both public health and environmental protection objectives, prompting fast action when pollution incidents have been identified and thus avoiding damages endangering water bodies and water-dependent ecosystems. In this report, we can see the case of Heredia (Costa Rica), where innovative technology is providing the treatment necessary to make surface, turbid waters safe to drink. The technology is employed to monitor water quality, collect water sediments, and identify poor drinking water status.

The solutions that technologies provide do not stop there. BEDC, which is being built in a district in the city of Busan (Republic of Korea), plans to create the conditions for testing a large variety of technologies to deal with water challenges at different stages of the urban water cycle. This innovative approach to urban water planning practices seek to deal with water challenges at different stages of the urban water cycle, increasing ecosystem resilience and harmonizing human life and nature. The urban development plan for the city puts integrated water management and ICTs at the core of future expansion of the city. The plan serves both public health and environmental protection objectives. Technologies to monitor, purify, distribute, use, and reuse water within the city with great precision are expected to make it possible to protect the environment, improve water quality, respond timely to flood risks, fight urban heat island, treat waste water, etc.

All these different initiatives provide evidence of how smart policies and technologies have helped to deal with current urban water challenges in different cities and in different circumstances. They have shown the

improvements achieved in urban water services provision and have suggested promising venues for future technological and policy developments.

While information on smart practices is essential, knowledge is still inconsistent with regards to the impact of ICTs on the urban water system. Although illustrative, case studies tell us little about the conditions to export solutions from one city to another. In addition, they are limited in how they single out areas for improvement and do not aid in defining appropriate levels for urban water performance. When the local circumstances and challenges are so diverse, replicating and scaling up or down is a complex matter. As a result, certain key questions remain unanswered:

- To what extent are water technologies delivering against the far reaching, current, and future urban water challenges?
- To what degree is the implementation of smart water technologies creating "Smart Water Cities"? When does a city that implements ICTs in the water sector become a "Smart Water City"?
- Can we identify different degrees of "smartness" in a city, with areas where progress has been made and others where progress is still lagging?

These questions highlight the need to develop an assessment method capable of examining and benchmarking cities so that we can evaluate how smart water systems are. Such analysis should tell us about the different functions of water in urban settings, about how and to what degree the proposed smart solutions address those functions, and whether these solutions are sufficient and adequate enough so that their implementation can qualify cities as a "Smart Water City". This assessment method can help to identify the elements that facilitate the implementation of smart and sustainable water solutions in cities. It can also help to identify the barriers that policy makers and water professionals are likely to face, thus becoming a valuable guidance for cities.