Climate change and Smart cities: A study on the application methods of water circulation technologies for smart city

By

AN, Kiyong

CAPSTONE PROJECT

Submitted to

KDI School of Public Policy and Management

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Committee in charge:

Professor Jung, Yongbae, Supervisor ____________________

Professor Lee, Junesoo ____________________

Professor Joo, Yumin ____________________

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Climate change and Smart cities: A study on the application methods of water circulation technologies for smart city

Kiyong An

I. Introduction

According to the Guardian (2020), Oxford dictionaries selected "climate emergency" as the word of 2019. This means that we should make solutions to resolve this climate related problems as soon as possible. Due to this, there has been a growing interest in climate change and a large number of studies on the cause of occurrence and solutions have been conducted in recent decade (Haunschild, et al., 2016). In this regard, UN (2007) states the main reason of the climate problem is caused by greenhouse gases, hereinafter GHG, that is released from cities. About 75% of all GHG on Earth is released in the cities we live in. In addition, UN (2018) projects that 68 percent of the world's population will live in urban areas by 2050. In other words, the climate crisis will expand further and have a great adversely impact on our lives. Climate change is seriously affecting our daily lives, especially in terms of water management. European environment agency (2020) argues that a key element of climate change is the impact on Earth's water cycle. According to Trenberth (2011), as the Earth's temperature rises by 1 degree Celsius, the water holding capacity of air will increase by about 7 percent, which cause more water to be concentrated in the atmosphere. This phenomenon has led to an increase in extreme precipitation event, which eventually leading to flooding and drought in other areas. Indeed, many countries have recently suffered from floods and droughts they have not experienced (Schwartz., 2018). So, there has been much effort to find solutions to climate-related problems including water management in city itself.

Recent research (Jiang, et al., 2017) argued that many studies focused on urban planning have been conducted to cope with climate change. UN-Habitat (2015) proposed city development strategies to respond climate change. Among these studies and policies, the smart city is currently receiving the most attention. It has been seen the best method to cope with climate change and improve the quality of life in the city.

Much research, however, has drawn attention to theoretical strategy and skills. And the understanding of smart city is very different among developers. Because a smart city includes a very wide range of technologies and strategy, some cities define smart city by simply installing a simple CCTV on the road (ETGovernment, 2020). Due to these problems, when developing a smart city, many officers and even engineers often approach it from a theoretical point of view without sufficient understanding of the characteristics of the target cities and meanings of smart city. This has been a factor that hinders project performance. So, I intend to present practical ways to develop smart city projects focused on efficient water management.

This paper aims to present practical methods for officers and engineers focused on water areas such as flood and drought. This paper will contribute to enhancing city developers' understanding of smart cities and technological applications.

To do so, there are three questions to identify solutions. First, what is the definition of the smart city and what features should it have to cope with climate change? In the second, what are the technologies that meet the requirements, and what is the priority among them? Finally, how can these priorities be applied practically considering the current state of the target cities?

I will conduct a literature review to identify definition and demanded features of smart city at first. And I will analyze the water-related technologies for adopting urban using data of K-water that is Korea's state company and conduct a case study.

This paper is divided into four sections. The first section will present a literature review on the status of smart city development and research. Through this, the demands of smart city by major cities and the necessary technical fields will be derived. In the second, I will analyze the water-related technologies status and level in K-water. In the third, I will present the applying method of technology for developing smart cities. Finally, there is a conclusion.

Ⅱ. Literature Review

A. Overview of climate change and response status

1) Overview

Climate change was first used academically by Wallace Broecker of Columbia University to pronounce global warming in 1975 (NASA, 2012). He defined global warming as the increase in Earth's average surface temperature due to rising levels of greenhouse gases and climate change as a long-term change in the Earth's climate, or of a region on Earth. He used these terms to warn climate problems caused by global warming. Since then, the rapid expansion of cities and populations has made more GHG emissions, leading to a number of climate-related problems. In fact, according to Acevedo and Novta (2017), between 1990 and 2014, there were about 8,000 natural disasters related to climate, and if there were no implementation of countermeasure for a reduction of greenhouse gas, the figure will be expected to increase.

A recent big bushfire in Australia is a case in point. Much of territory, about the same size as Korea's, was burned down for about four months (BBC, 2020). Many researchers have suggested a lack of response to climate change as the reason for the outbreak. Australia is a leading producer and exporter of fossil fuels such as coal, while showing low resilience to climate problems (Nuccitelli, 2020; Gramling, 2020). Australia ranked 54th out of 61 countries in the Climate Change Performance Index, which shows the country's ability to respond to climate problems (CCPI, 2020). And the rise in sea level caused by climate change is also threatening the people's lives, especially in the coastal area. In Jakarta, 60% of the northern region is already below sea level (World Bank, 2011). Namely, we are living in a time of climate emergency.

So, how did this climate change occur? A great number of organizations such as the UN and EPA selected the GHG emissions as main reasons. 60 percent of total GHG has been released from cities due to excessive use caused by rapid urbanization, and this phenomenon was expected to worsen (IPCC, 2019; see also EPA, n.d.; UN, 2018; UN, n.d.).

2) Water stress

This climate change makes water management worse for flood and drought. According to Schwartz (2018), duration of precipitation with high record had increased more 25 percent for 14 years, 1980 to 2013, in the Central and Eastern US. On the other hands, sub-Saharan Africa was suffered from lack of rain. Dry month duration was increased about 50 percent during same period. These change makes more floods and droughts, which are fundamentally threatening the lives of urban residents. So, water stress term has been used to indicate the extent of damage caused by floods and droughts.

EEA (n.d.) states that water stress occurs when demand for water exceeds the available amount or is not met due to poor water quality. In this regard, Hofste, et al. in World Resource Institute (2019) classified water stress indices by country. They argued in the report that 17 countries, which account for about a quarter of the world's population, are suffering from extremely high-water stress. And 27 countries also have high water stress (Fig 1). Looking at the distribution of countries suffered from water stress, most of them are in the Middle East and North Africa area, regardless of their economic power (Fig 2). These countries have common things that the region is hot and dry, so water supply capacity is relatively low and growing demands have forced countries to make difficult water management. In addition to, their main industry is agriculture with high water consumption, which adds to the difficulty of water management.

Nevertheless, most countries have failed to secure additional water supplies such as desalination, water reuse, etc. According to World Bank Group (2018), 82% of wastewater in that area is not recycled. This situation will be exacerbated by climate change, economic growth, and rapid urbanization.

EXTREMELY HIGH BASELINE WATER STRESS

1. Qatar
2. Israel
3. Lebanon
4. Iran
5. Jordan
6. Libya
7. Kuwait
8. Saudi Arabia
9. Eritrea
10. United Arab Emirates
11. San Marino
12. Bahrain
13. India
14. Pakistan
15. Turkmenistan
16. Oman
17. Botswana

HIGH BASELINE WATER STRESS

18. Chile
19. Cyprus
20. Yemen
21. Andorra
22. Morocco
23. Belgium
24. Mexico
25. Uzbekistan
26. Greece
27. Afghanistan
28. Spain
29. Algeria
30. Tunisia
31. Syria
32. Turkey
33. Albania
34. Armenia
35. Burkina Faso
36. Djibouti
37. Namibia
38. Kyrgyzstan
39. Niger
40. Nepal
41. Portugal
42. Iraq
43. Egypt
44. Italy

Fig 1. National water stress ranking (World Resource Institute, 2019)

Fig 2. The Middle East and North Africa Region (World Bank Group, 2018)

The problems of securing and managing water resources caused by climate change will have a significant impact on the national economy, beyond the disasters and water supply. As presented in the figure (Fig 3) below, the impact on the economy increases relatively in areas where water stress is high. It also comes more seriously that these problems cannot be dismissed as a problem of only a few countries. Therefore, it is time to actively respond to climate change in terms of water resources management.

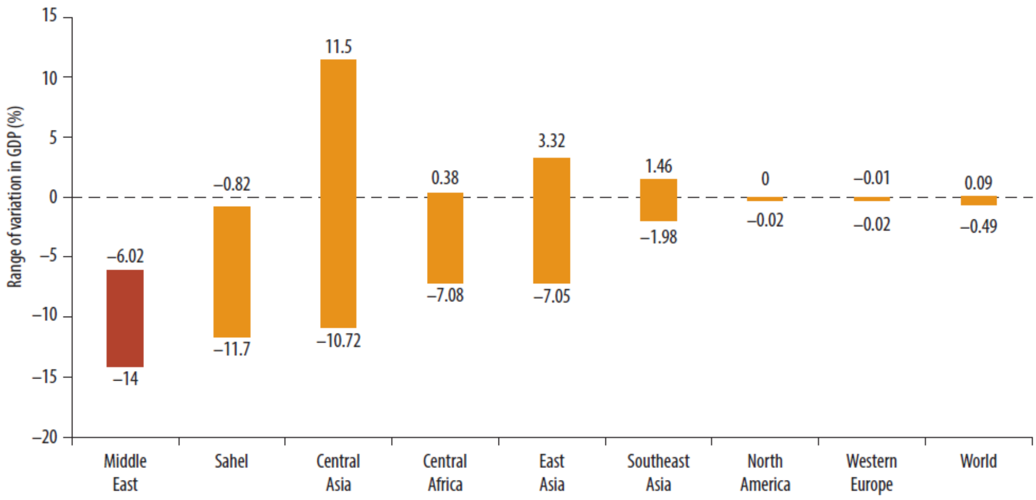


Fig 3. The Economic impacts of climate change-induced water scarcity by 2050 (World Bank Group, 2018)

3) Response strategies over climate change

There has been a growing interest in identifying many countermeasures over problems of climate change (Nature Research, n.d.). Among them, I think we need to focus on the remark of Maimunah Mohd Shari who is executive director of UN Habitat. She said in 2019 that "Cities around the world are the main cause of climate change but can also offer a part of the solution to reducing the harmful greenhouses gases that are causing global temperatures to rise". This remark highlights the importance of cities to tackle climate change. Under this basis, all stakeholders such as international organizations, governments, corporations, and people are implementing the measures in follow four forms.

Fig 4. Measures being implemented to cope with climate change

The first are agreements between countries. Climate change is a global problem and cannot be solved by the efforts of some countries. Therefore, global cooperation in solving climate problem is essential. From this point of view, Europe was a priority region to actively respond over climate change. In 2007, the European Council adopted new strategy on energy and climate change for 2020. According to this strategy, all EU members set goals to reduce GHG emissions by 20 percent, to increase the proportion of renewable energy to 20 percent, and to enhance energy efficiency by 20 percent (European Commission, 2010). The most important agreement, however, is the Paris Agreement in 2015 (Bodle, et al., 2016). This agreement is a landmark in international climate policy. 195 nations in the world came to consensus to combat climate change. Each country decided to minimize GHG emissions at pre-industrial level and the world pursuit to limit temperature increase to 1.5 degree Celsius. "2020 The Climate Turning Point Report" was subsequently published, which presented six milestones for reducing carbon emissions (Fig 5). Each of the six items set short-term goals up to 2020 and long-term goals up to 2050 as representative areas of implementation for carbon emissions and energy savings. What is noteworthy here is that most of measures over climate change currently being implemented and reviewed across the world are following these six milestones' strategies (Revill & Harris, 2017; M2020, 2017). The main contents of this milestone are expanding the supply of renewable energy, reducing carbon emissions, and expanding infrastructure investment for achieving these goals.

In addition to this, cooperation between various countries and cities such as C40, which is a climate change consultative in major cities, is underway (C40, n.d.).

Fig 5. Six Milestones by 2020 (M2020, 2017)

Second is government policies on climate issues by country. In accordance with the objectives and milestones described above, there are movements to reduce GHG emissions by implementing regulations and policies through legislation. These policies include to allocate carbon quotas, impose carbon taxes and shift energy source to renewable one. Based on these policies, Copenhagen declared that it will be the world's first carbon neutral city (Eskander & Fankhauser, 2020; Dubash et al. & The City of Copenhagen, 2012). After that, many countries have followed that their city will be a carbon neutral city (Laine, et al., 2020). C40 Cities defined a carbon-neutral city as it should achieve net-zero GHG emissions within a given period. This means that the city must achieve the goal of net-zero GHG emission from our daily life, such as supply and consumption of various types of energy, transportation, and waste disposal, etc. (C40 cities, 2019). Korea government also announced their strategy for carbon neutral city (Korea government, 2020). This strategy presents three major policy directions and ten major tasks. The goal is to become a carbon neutral city by 2050 by expanding the use of renewable energy, revitalizing the low-carbon industry, and establishing governance for a carbon-neutral society.

Third is active research and technologies development. A significant amount of research has been conducted to find solutions by improving urban planning that is focused on cities. Jiang et al. (2017) analyzed the status of urban planning research in response to climate change from 1960 to 2016. He argued that much research in the following four fields, forming mechanism, assessment and analysis, spatial simulation and adaptation planning and city response and governance, has been conducted as countermeasures against climate change. Gray (2017) also presents five areas of technology application to cope with climate change. It is power generation, transport, food, manufacturing, and buildings. These five sectors are the main source of GHG emission. Transportation and food, for example, account for 23% and about 45% of global energy-related CO2 emission, respectively. What is noteworthy here is R&D bodies for reducing carbon emissions of cities are not limited to government or research institutions. In fact, Toyota corporation announced their Woven city project plan at CES in 2020 (Toyota, 2020). The world's leading automobile manufacturer addressed that they would develop future green city, and that plan was announced at very popular electronic convention. All elements in this city such as self-driving vehicles, hydrogen fuel cells, household electrical devices and infrastructure are connected using information and communication technology. They hope that these collected data make it easier for officials and citizens to respond to disasters related to climate change and use them efficiently within limited resources. I think this city development case tell us that urban development is no longer just public sector.

Final is "Green new deal". In fact, the applications of international cooperation, government policies and technologies described above to actual projects are essential to cope with climate change. This requires large-scale infrastructure investment. From this point of view, the term "Green New Deal", which was created by adding the meaning of eco-friendly green growth attached to the New Deal policy that was mobilized to escape the Great Depression in the 1930s is widely used (Rifkin, J., 2019). The term "Green new deal" was first used by Thomas Friedman, Pulitzer Prize-winner, in 2007. He recognized that the unusually high temperatures that continue to occur were caused by climate change and advocated the need for transition in energy policy that relied on fossil fuels to embrace for climate problems. He also suggested the need for large-scale industrial policies with green technologies (D'Souza, D., 2020). This Green New Deal became more imprinted on the public after the U.S. Congress submitted a resolution. The resolution, submitted by the US Senate, S.RES.59, and the House of Representatives, H.RES.109, represents that the Green New Deal is not just about climate change, but is essential for sustainable prosperity. In other words, the Green New Deal is being proposed as a measure to address social and economic inequality along with climate change issues. This resolution has five major goals. First, achieving carbon neutrality, secondly creating high-quality jobs, thirdly infrastructure and industrial investment in sustainable way, fourthly ensuring a sustainable and healthy environment for all generations, and fifthly promoting justice and equity by banning the socially disadvantaged. To achieve this goal, projects such as the converting energy sources to clean energy, improving energy efficiency, and establishing sustainable food, water management systems and restoring ecosystems were presented. Although the resolution was rejected by the U.S. Senate, it is considered symbolic in that it presented a structural transition to address social problems as well as the climate crisis (KEI, 2020).

Fig 6. Announcing the resolution 109 (Friedman, L. in The New York Times, 2019)

Then, what kind of project can achieve this the goal of Green New Deal? In February 2017, a high-level seminar was held entitled “Investing in Europe: building a coalition of smart cities & regions towards a Third industrial Revolution” hosted jointly by the European Committee of the Regions and the European Commission. This seminar discussed ways to achieve the goal of Europe’s decarbonization and the transition plan toward green era in 2050. The vice-president of the European Commission, Maroš Šefčovič, highlighted that a sustainable future depends on the achievement of regional and urban goal. This meant that it would depend on the expansion of the optimized green infrastructure and the increase in energy efficiency in each region or city (Rifkin, J., 2019). It is the smart city that is being implemented by applying these concepts. As above described, main source of GHG emission is city, so many countries and cities are trying to find solutions in the city itself. From this perspective, smart city is the comprehensive urban development solutions that many governments and researchers have proposed to cope with climate change. Indeed, many major cities like LA and New York, are trying to develop smart cities as part of the Green New Deal. The local government is actively seeking to introduce renewable energy by replacing fossil fuels that are being depleted, thereby reducing carbon emissions, and improving the quality of citizens’ life (Teale, C., 2019). The smart city, which is a new urban design concept that considers all these city components is drawing attention as a concept and technology for responding to climate change (Dent et al., 2020; Smartcity, 2018). I also focused and described these smart cities in this paper. With a focus on effective water resource management, I stated the definition of “water circulation smart city” and suitable technical application methods.

B. Case study: the city case of having water crisis and efficient water management

As described above, the water crisis caused by climate change is equally affecting the entire world. Different results, however, are being produced depending on the degree of response to the water problems faced by each country. Therefore, this chapter will provide some case studies to demonstrate the importance of effective water management.

1) Negative case: “Day zero” in Cape town, South Africa

Cape town is the second-largest economy and populous city with 3.7 million population after Johannesburg in the South Africa. The city is also the legislative capital city where the National Parliament and many government offices are located (Municipalities of South Africa, n.d.). Such big and important city, however, have recently suffered from serious water shortage due to continuous drought (Burls et al., 2019; Alexander, 2019).

In January 2018, Cape town officials accounted that the city was three months away from running out of available water. They called it as “Day Zero”. It meant that the city cannot supply water to citizen due to depletion of water resources. The world was stunned by the possibility of such a water shortage in major city. The residents had no choice but to line up to get a daily supply of water, and there were even people who took seawater to get water for toilets (Fig 6~7). All use of water outside the home such as car washing, or garden irrigation was banned, and all water use per person in home was limited about 50 liter per day. Local government launched water police to monitor illegal water use (Welz, 2018; Sparks, 2018).

Fig 7. Residents queue to fill containers with spring water in Cape Town (Alexander in Bloomberg CityLab, 2019)

Fig 8. Interview: Salt water from beach just to use for the toilet (Journeyman Pictures in Youtube, 2018)

The direct reason for the occurrence of Day Zero is a three-year drought caused by climate change. Failure for water management, however, was another reason. Specifically, the lack of precipitation forecasting technology and the failure to develop new water resources made it impossible to secure sufficient water resources for drought. In addition, the failure of demand control due to agricultural-oriented industries like wine production, which needs a lot of irrigation water, had deepened these problems. It has evolved into another problem of inequality. According to Makou (2017), 65 percent of the avail water resources were supplied to the formal residents for essential and nonessential uses such as swimming pools and gardens, while just 3.6 percent were supplied informal residents, which account for about one-fifth of the total population. this was a matter of basic right for human, it created considerable social resistance.

2) Negative case: "Jakarta is sinking" in Jakarta, Indonesia

Jakarta, the capital, is the main city for Indonesia's growth. The city currently has a population of about 10 million and plays a key role in Indonesia's economy, society, and culture. In addition, numerous global companies such as Unilever, Google, and Marriott International have entered the market. Such mega city has recently faced big challenges. That is the issue of capital relocation. In fact, Jakarta has many social problems such as congestion, slums, sanitation, etc. The most serious problems of all are land subsidence and natural disaster like floods caused by failure of water management (TOMTOM, 2019; The Jakarta Post, 2018).

In the recent 60 years of Jakarta's remarkable economic development, the population has nearly quadrupled. Jakarta, which accounts for 0.3 percent of Indonesia's total territory, is responsible for 17% of Indonesia's total GDP (BPS-Statistic Indonesia, 2019). This soon led to the world's highest level of overcrowding. In contrast, infrastructures like a tap water system for supporting residents was not sufficient. Many residents in Jakarta have come to rely on groundwater as their water resources instead of tap water system. About 64 percent of Jakarta's water sources are currently groundwater (Abidin et al., 2011). The problem is that most of citizen are using unregistered wells and the government does not have enough equipment to monitor groundwater use. This phenomenon eventually leads to land subsidence. Jakarta is sinking now. The northern Jakarta located in coast has subsided about 4m over past 100 years (Deltras, 2015). In addition, rising sea water level caused by climate change make the problems even more serious. Seawater invades coastal area, and low-lying areas by land subsidence are suffering from inundation damage due to continuous flooding (World Bank, 2011). This prompted the Indonesian government to announce the relocation of the capital. It is also making effort to secure infrastructures for efficient water management (Lyons, 2019; Bambang & Brodjonegoro, 2017; PPP Knowledge Lab, n.d.).

Jakarta is a representative example of water management's importance as an essential factor for the sustainable growth of the city.

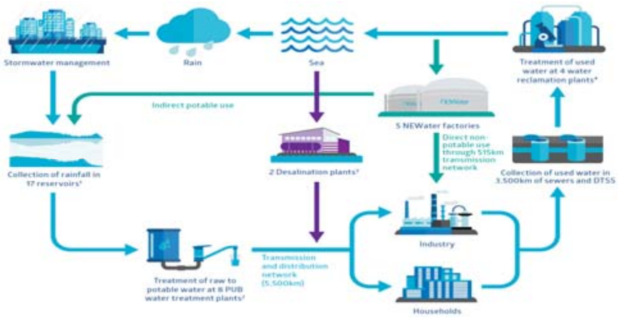
3) Positive case: “4 Taps Strategies” in Singapore

Singapore is an island country located at the southern tip of the Malay Peninsula in Southeast Asia. Singapore separated from Malaysia and became an independent state in August 1965. In early days of independence, Singapore had many serious problems. Most of all, most of the territory was mudflats. It meant that the condition for living and economic development were very poor. At that time, first prime minister, Lee Kwan-Yew, makes a famous remark of “from mudflat to metropolis” to show the blueprint of Singapore's development (Xuanwei, 2015). There, however, was a more important issue that the land condition. It is water. As described above, since Singapore is an island country, it was very important to secure sufficient water resources. The problem is they cannot supply demand water quantity due to their small catchment area. So, Singapore relied on Malaysia for much of its water resource, about 60 percent of demand quantity, in accordance with the agreement signed between two countries. (Ghangaa, 2018). The high dependence of water resource can always be a threat depending on the relationship between countries. In addition, the impact of climate change can make it more difficult to secure water source in domestic. Under these conditions, Singapore was expected to become the world's highest water stress country (Maddocks et al., 2015)

Fig 9. Schematic of imported water (PUB, n.d.)

Fig 10. Water pipeline (Sim in Straits Times, 2018)

As a countermeasure, the Singaporean government has adopted and implemented the "four tap strategies" for sustainable water supply and demand management (PUB, 2014). The key to this strategy is to secure additional water resources and reduce reliance on imported water to prepare for increasing water demand and climate change. Here, the "4 taps" means four different water sources (Fig 11, Fig 12). The first of these is securing additional water resources in the catchment area. Nearly all rainwater in two-thirds of Singapore area will be harvested and stored in 17 reservoirs. Second is imported water from Malaysia. The amount of imported water will decrease gradually. Third is NEWater. In other words, reclaimed water. Most of used water will be recycled and treated for meeting water demand. This NEWater will meet up to 55 percent of Singapore's water needs by 2060. Final is desalinated water. In the meantime, use of desalination water has been poor due to technical problems and high production costs despite of very abundant amount. With continuous developing technologies and building desalination plants, however, they are increasing the use of desalination water. Through these effort, desalinated water will meet up to 30 percent of its water needs. The point to note here is these two sources, reclaimed and desalinated water, will supply up to 85 percent of water needs by 2060. I think many countries struggling with water shortage should refer the "four taps strategies" for resolving their water shortage problem. With the increasing water shortage due to climate change, securing new water resources such as water reuse and desalination is becoming essential.



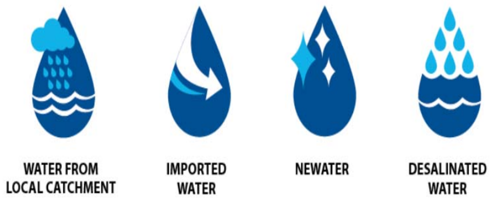


Fig 11. The water loop (PUB, 2014) **Fig 12. Four national taps (PUB, n.d.)**

As an implementation method to achieve goals described above, Singapore introduced smart technology. Singaporean Prime Minister, Lee Hsien Loong, announced the Smart Nation Initiative in 2014 to get Singapore's sustainable development and improve better quality of life (Khern, 2019). The core of Singapore's Smart Nation Plan is the connectivity of data. Data gathered from all sectors of Singapore is integrated, managed, and analyzed to support government decisions and citizen's daily lives. The government has set up three major pillars, digital government, digital society, digital society, to become smart nation and incorporates various smart technologies (Fig 13). Specifically, in the water management sector, the PUB, Singapore's national water agency, rolled out their smart water metering program. Through the plan, about 300,000 smart water meter like advanced metering infrastructure (AMI) will be installed in residential, commercial, and industrial complex by 2023. This system automatically reads the water consumption data several times a day and sends it to the PUB. The transmitted data will be collected and analyzed by PUB. And using this data, PUB will carry out water quality management and emergency restoration of the lead pipe. In addition, relevant data is delivered to consumers through mobile applications on online portal, etc. for demand management (PUB, 2019).

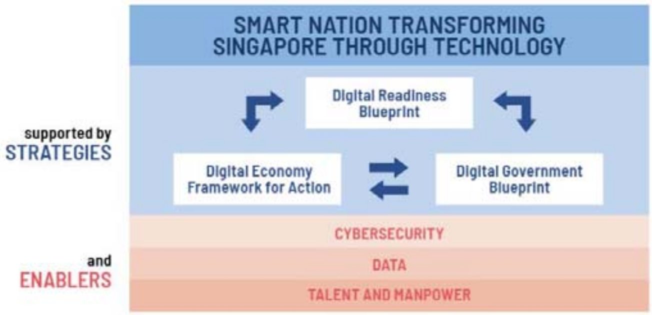


Fig 13. Smart nation framework (Khern, 2019)

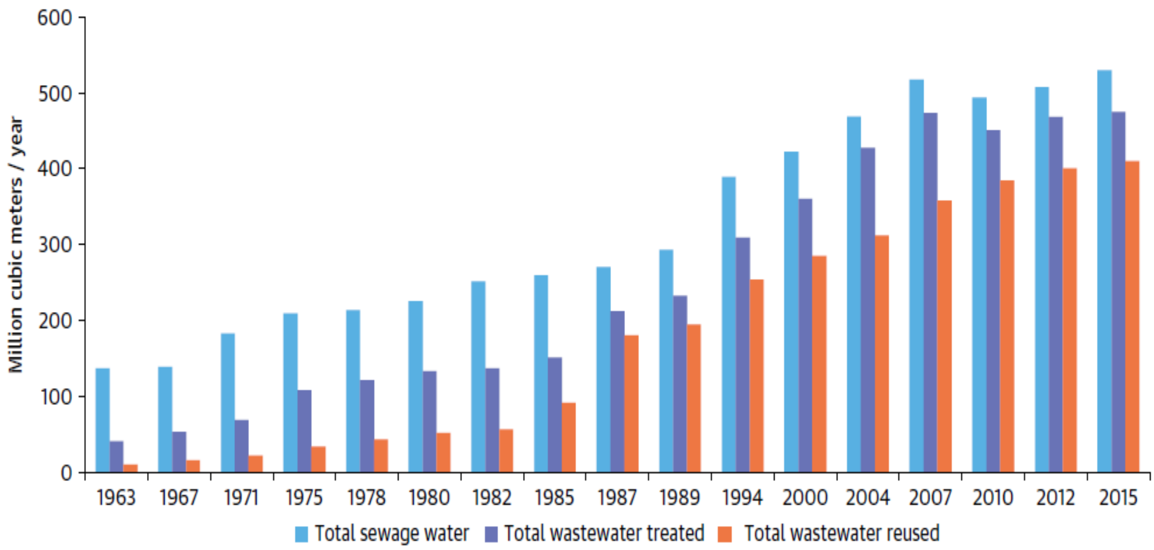
Fig 14. Smart water meter (PUB, n.d.)

4) Positive case: Nine innovations in the Israel water sector (Marin, et al., 2019)

Israel is also the most serious water-stressed country like Singapore due to their geographical condition and climate change. Territory is composed of 2 over 3 deserts and 1 over 3 semiarid regions. Annual rainfall deviation is very severe, in the south area 600-millimeter and north area 150-millimeter, continuous drought occurs frequently. In addition, about 70 percent of rainfall is lost to evapotranspiration, and about 25 percent infiltrates to ground, so only 5 percent of precipitation flows to the surface. Due to these unfavorable conditions, Israel is experiencing great difficulties in water management. In addition, these difficulties were expected to be exacerbated by growing population and climate change.

Overcoming these difficulties had led to the development of Israel's water management technologies and policies over the past 50 years. By combining institutional reform with continuous infrastructure investment, Israel has been able to overcome their bad hydrologic conditions and supply reliable water. This chapter presents the nine innovations Israel is carrying out, by summarizing the report, Marin, et al., in World Bank, in 2019.

First innovation is national water system to connect all water infrastructure. As described above, much water was lost due to evaporation. So, by establishing a national bulk water transmission system, about 95 percent of freshwater resources can be delivered to local water suppliers while minimizing the amount of loss. Second innovation is large-scale reuse of wastewater. Increasing use of reclaimed water is essential for Israel considering their hydrologic conditions and increasing amount of demand water due to population growth. They have increased the wastewater treatment infrastructures and supply it to end-user. Reclaimed water accounts for more than 40 percent of the irrigation water, and more than 87 percent of wastewater is currently being reused (Fig 15). Third innovation is building large-scale desalination infrastructures. Israel actively secured addition water resources by taking advantage of its coastal location. Five mega desalination plants with a total capacity of 585 million cubic meters per day using reverse osmosis technology were constructed along the Mediterranean coast. Desalination water currently accounts for more than 85 percent of urban water consumption and 40 percent of country's entire water consumption.



Sources: Israel 2012; Israel Water Authority website.

Fig 15. Collected, treated, and used sewage for 1963 to 2015 (Marin, et al., 2019)

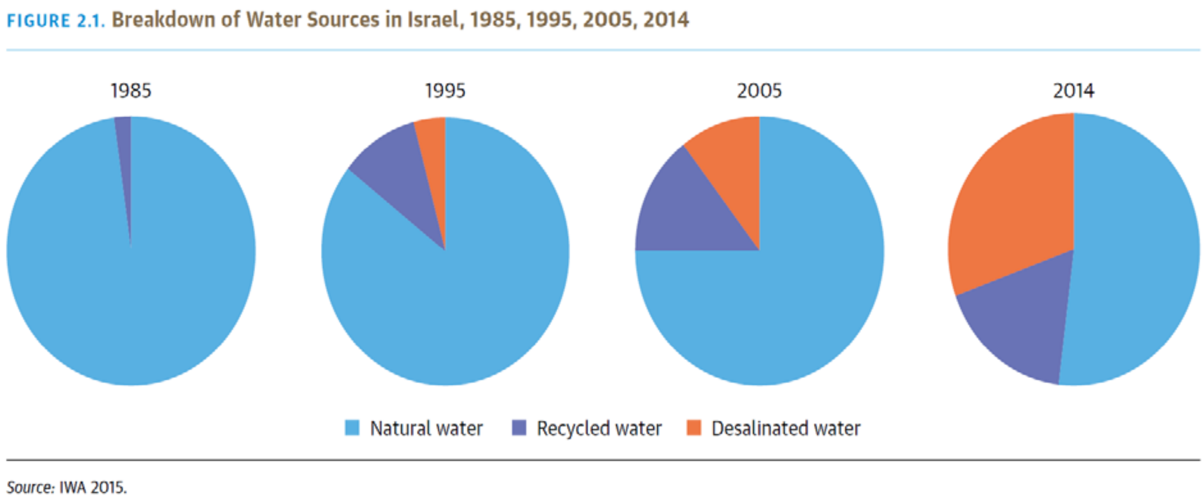


Fig 16. Breakdown of water sources in Israel (Marin, et al., 2019)

The fourth innovation is using aquifers as reservoirs. In the past, when the development of additional water resources was insufficient, the aquifer was overused as water resources. With the development of alternative water resources, however, the aquifer could act as a reservoir. It is refilled with treated wastewater during periods of low demand and monitored comprehensively. The aquifer serves as a buffer against high demand while minimizing evaporation losses. The fifth innovation is interception of surface water run-off and recharge. There are many flash floods due to rainfall patterns and bare landscape in Israel. It is another reason of water loss. So, retention infrastructure such as small dams, was built to prevent useless runoff. Although the amount collected is relatively small, these efforts are constantly being carried out. Sixth innovation is to prompt crop selectivity and import virtual water. In fact, agriculture is major user of water. According to USDA (n.d.), agriculture accounts for about 80 percent of water consumption in USA. Israel is also one of country established based on agriculture. This means that agriculture will take up most of the water resources. So, the policy was carried out to change cultivated crops to ones that require less irrigation water, and to procure crops that require much water through imports. It can be seen as a kind of demand-control policy. Seventh innovation is also related to agriculture. It is the development of efficient irrigation technologies. Given the water shortage situation, it is important to increase crop productivity with limited water resources. Through the application of technologies such as drip irrigation and mini sprinklers, the productivity of water use in Israel continues to increase (Fig 17). Eight innovation is public awareness for demand management. Demand management is as important as securing new water sources. Under the motto of "the base for change is public acceptance", the government is promoting water conservation and at the same time distributing water-saving devices. Through these efforts, water consumption per capita continues to decline (Fig 18). Last innovation is creating a supporting environment for water innovation.

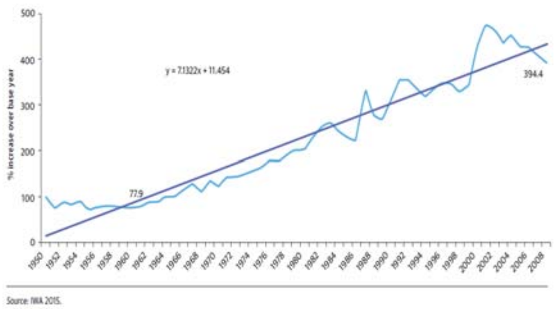


Fig 17 Water use productivity in Israel

Fig 18. Water consumption for 1997-2013

C. New concept and technology to cope with climate change and population growth

As describe above, climate change and rapid urbanization have serious adverse effects on water management. A variety of concepts and technologies are being developed by many institutions and researchers to overcome this crisis. This chapter presents some of these representative things.

1) WEF NEXUS (Water – Energy – Food)

Many institutions and governments are talking about the importance of water in the age of climate change. In addition, various technologies for stable water supply and disaster prevention have been developed, and policies accordingly are being implemented at this time. Water management, however, is closely connected with various elements of society. Therefore, it is necessary to comprehensively consider various factors related to water. It is WEF Nexus that comes from this point of view.

Water, energy, and food are essential to human life and are closely connected. In addition, considering the increase in population and urban areas, the impact of energy and food on urban areas should be considered for effective water management (Flammini, et al in FAO., 2014). Looking at the specific relationship between the three factors, the first is water and food. Agriculture accounts for about 80 percent of total water consumption. And it takes 7 times more water than wheat to produce the same amount of beef (Mit-ra Industries, 2018). The second is water and energy. While hydroelectric power plant needs water for electricity production, it takes electricity produced by power plant to operate purification plant for water supply. Finally, more than about 25 percent of global entire energy is used for production and supply of food (FAO, n.d.). Like this, comprehensive consideration of energy and food needs to be taken into account to establish a city or state water management plan for climate change and population growth. WEF-Nexus is the representation of this concept.

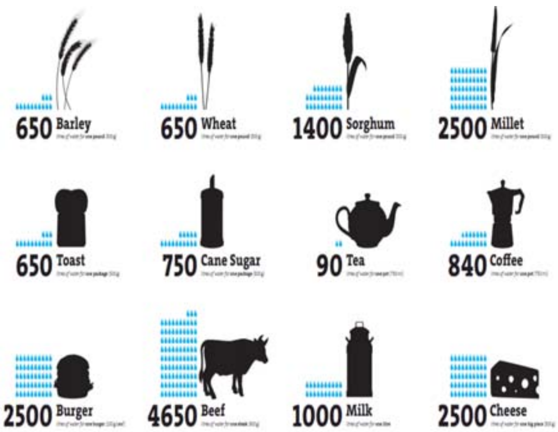


Fig 19. Virtual water (Mit-ra industries, 2019)

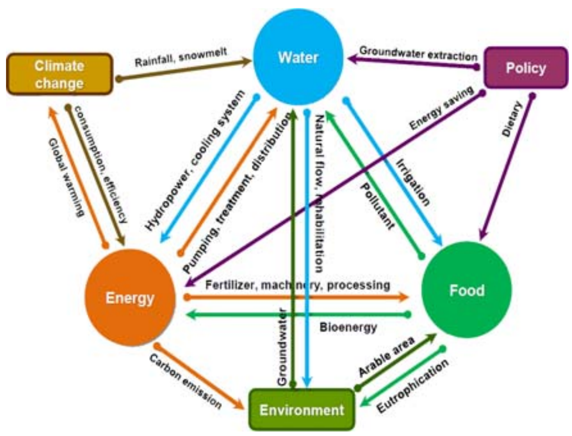


Fig 20. Relationship diagram (Kang, 2020)

WEF Nexus is new concept to ensure the sustainability of resources through planning and management. So, many researchers and companies have paid attention to combine smart technologies in water, energy, and food sectors for enhancing ability to cope with challenging problems (Kang, 2020).

2) Net-zero

Intergovernmental Panel on Climate Change suggests that to achieve the Paris Agreement's temperature goals, global warming should be limited to below 1.5 Celsius, the world need to reach Net-zero GHG around 2050 (IPCC, 2018). In accordance with this suggestion, many countries have set the GHS Net-zero emission targets and implemented related policies under consideration (Murray, 2020; Darby & Gerretsen, 2019). So, what is Net-zero, and why this policy is necessary to respond against climate change now? The Levin, et al., in WRI (2020) provides definitions of Net-zero and their needs as follows.

Definition of Net-zero emissions at the global level is "a balance between anthropogenic emissions and removals of GHG in a given time period." In other words, the sum of the amount released into the atmosphere in a certain area and the amount reduced in the same region is zero, which is different from the gross zero that has no emission into the atmosphere at all. The Net-zero concept is intended to prevent further global temperature increase. Since GHG emissions, however, are inevitable during industrial production and daily life, this concept has been introduced to reduce corresponding levels of GHG.

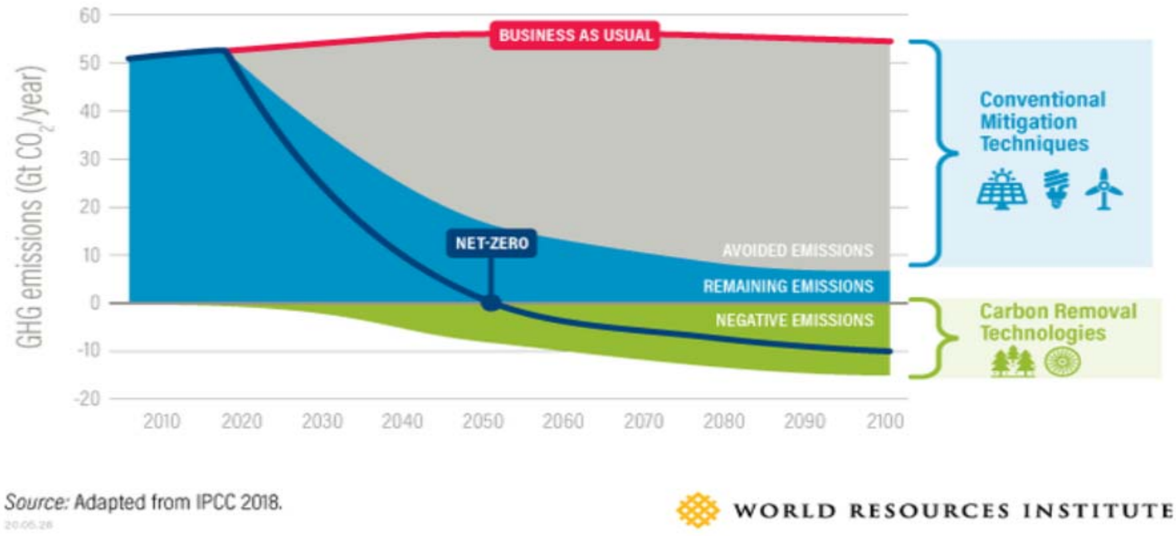


Fig 21. Staying below 1.5 degrees of global warming (Mulligan, 2020)

Most countries have set their target year as 2050 and are implementing policies and introducing technologies to achieve a carbon Net-zero goals (Darby & Gerrestsen, 2019). South Korea has also declared a carbon neutral country in 2020 with a goal of 2050 (Korea government, 2020). A variety of technologies and measures are currently being proposed by many companies and research institutions, such as expanding renewable energy and increasing energy efficiency to achieve Net-zero targets (Mulligan, et al., 2020; Nationalgrid, 2020).

3) Decentralized technologies

Living in the city requires a lot of energy, such as electricity and water. So far, most of this necessary energy relies on a few large-scale infrastructure facilities, such as water purification plant and thermoelectric power plant. As shown in the case of Korea (Fig 22), fossil fuel energy-based power generation systems like coal are the mainstay of the national energy supply. In most of these supply methods, large-scale infrastructure facilities are installed at points where it is easy to supply basic fuel like coal and river water for energy production and delivering them too long-distance. It is a so-called centralized management. This supply method, however, has many problems besides just the issue of fossil fuel depletion and environmental pollution.

Fig 22. Power generation share (MOIET, 2020)

The first is energy loss. All energy is lost in the transfer process. According to the EIA (2020), it is estimated that about 5 percent of the power is lost in the transmission and distribution process in the US. In the case of water, it is even worse. FAO (1989) indicated that the conveyance efficiency of canals for irrigation is as low as 60 percent. This meant that 40 percent of the water is lost in the conveyance process. The city is no different. Many cities have been suffered from high non-revenue water rate due to aged pipe and so on. The city of Yerevan, the capital of Armenia, recorded about 72 percent non-revenue water rate in 1997 (ADB, 2008).

Table 1. Indicative value of the conveyance efficiency (FAO, 1989)

Canal length	Earthen canals (Soil type)			Lined canals
	Sand	Loam	Clay	
Above 2000m	60%	70%	80%	95%
200~2000m	70%	75%	85%	95%
Below 200m	80%	85%	90%	95%

Second problem is that it is difficult to respond quickly to a crisis. Since most of the infrastructure is small number of large-scale facilities, it may be difficult to change operation way quickly to disaster situation and changes in demand. In addition, some equipment failures will inevitably cause damage to many areas that rely on them. Because of these characteristics, it is reviewed more than the required quantity in the design of infrastructure facilities. This soon leads to excessive investment, which in turn results in worsening economic feasibility. The most important issue, however, would be the GHG emissions and rising global temperatures due to fossil fuel use. It is not a sustainable way.

Energy decentralized management technology is emerging to compensate for these shortcomings. Instead of producing and conveyance long-distance with few large-scale facilities in large areas as in past, it is a management technique that allows production, distribution, consumption, and reuse by small areas (Fluence, 2020). The prerequisite for such a decentralized management technique to be realized is the introduction of renewable energy. In the case of solar and wind power, which are representative renewable energy sources, they may be easily installed anywhere. House and parks, which used to be only energy-consuming places, are now good solar and wind power plants. Production and consumption of energy can be done in same small region. This means that many losses can be saved during energy transmission and distribution. In addition, energy management by small regional units can be possible to response rapidly against disaster situation and changes in demand. As shown fig 23, decentralized management techniques are essential to expand the application of renewable energy to combat problems related to climate change. It is a sustainable energy management method. The expanded application of such decentralized management techniques is being implemented through government policy. The Korean government decided to expand the proportion of decentralized power generation near the demand area by using renewable energy and fuel cells to 30 percent over 40 years (MOIET, 2019).

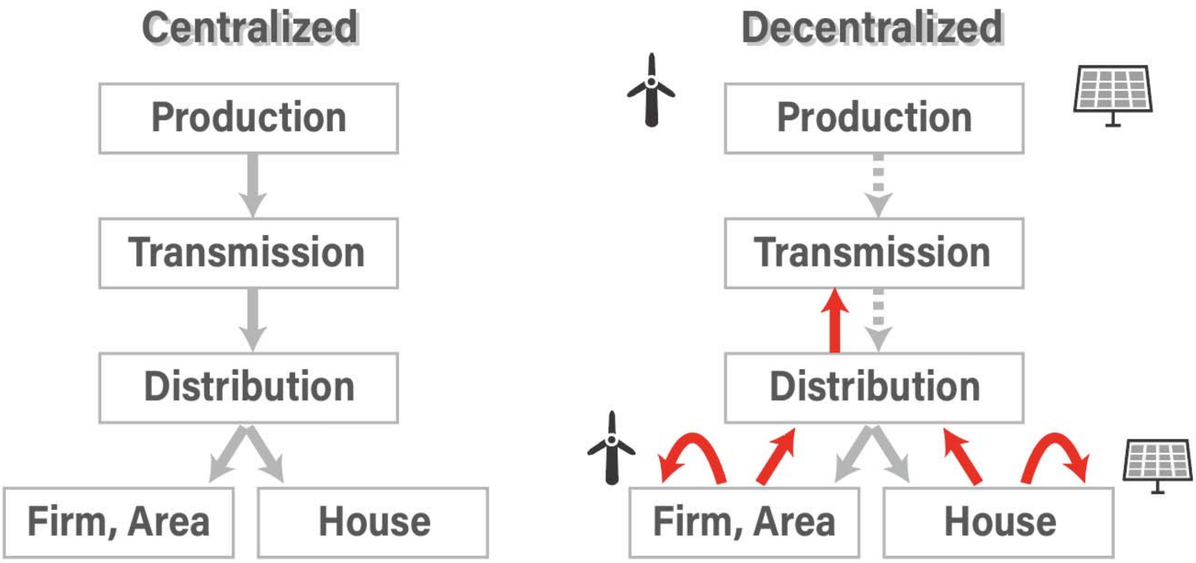


Fig 23. Comparison of resource management methods (Coursera, n.d.)

Therefore, these decentralized management technologies need to be applied to cities that will be developed in the future to efficiently use energy and reduce carbon emissions. This will be an important factor in determining the success or failure of smart cities.

This decentralized technology, however, is not better in every way. Production and consumption in small regions mean an increase in the number of facilities to be managed. Skilled technicians managed just a small number of facilities in the past, but decentralized management required to manage more facilities at the same time. In addition, larger cities or countries covering small regions should be able to manage many of the facilities that are being operated and distributed. In the event of an accident such as pipe damage in some areas, it should be possible to supply immediately by utilizing the available energy resources of the adjacent areas. In other words, a better planned operating system and skilled technicians are necessary more than existing centralized method (UNESCAP, 2012).

Smart management and smart grid are technologies that are being introduced and applied to compensate for these weaknesses of decentralized management. First, smart management technology is a system that secures data produced in all process such as production, transmission, and consumption and uses it to make decisions necessary for planning and operating facilities. This smart management technology can be divided into five stages: data collection, data transmission, data interpretation, data manipulation, data presentation. The important part of this is that all data should be available in real time, and that it should be processed and interpreted for the purpose of use. In addition, such data should be disseminated not only to facilities managers but also to consumers, for making each necessary decision easier. The second is smart grid that was used first for electricity management. By applying information and communication technologies to the power grid that connects various decentralized power source and consumers, it enables integrated power supply management between regions. If the supply of a specific area is expected to be insufficient depending on the situation of the power source, the excess can be supplied to other regions by checking the supply availability other adjacent areas. This requires the ability to exchange bidirectional information between suppliers and consumers based on information and communication equipment such as smart metering and the internet of Things (IoT). Through this, intelligent demand management and renewable energy linkage can be facilitated (KSGI, n.d.). these smart grid concept extend to other sources of energy. In the water field, the word smart water grid is being used. Decentralized water management is being implemented by applying technologies such as small-scale vertical water purification plant, smart metering, and IoT.

Korea's Ministry of Environment selected decentralized water management as one of the top 12 key technologies in R&D Roadmap 2030 for future water management technology. Various technologies such as small-scale water purification and sewage treatment plant, optimal wastewater treatment by source, LID, low impact development, etc. is currently being researched and implemented to develop smart cities (ME, 2019).

Ⅲ. Smart city

In the previous chapter, I explained the causes of climate change and international movement, various technological concept to cope with it. Many countries currently have selected smart city as a way to apply these policy goals and technologies and are conducting various projects (B The Change, 2016; Ovington, n.d.; Willige, 2020). There, however, are so many different definitions and implementation plans for this smart city for each business entity. So, this chapter will suggest the definition and requirements of smart city focusing on water management to resolve problems due to climate change.

1) Definition

In fact, a generally accepted definition of the smart city still lacks clarity (Smart Cities Missions, n.d.). The term smart city is used in many parts of the world, but its purpose is different. Many people are confused by the different definitions of what is a smart city and what elements it should have. So far, many project developers and engineers are struggling to apply technology due to lack of understanding of smart cities. In fact, some cities define smart city by simply installing a simple CCTV on the road (ETGovernment, 2020).

In recent decades, many scholars defined the smart city (Table 2). First, Barrionuevo et al. (2012) has defined smart city as the city that utilizes all available technologies and resources in an intelligent and coordinated way for sustainable development. Likewise, Albino et al. (2015) argued that a smart city is a strategy to alleviate the problems caused by urban population growth and rapid urbanization. Among these various definitions, what I pay attention to is the application of ICT, information, and communications technology, in urban planning to solve the problem caused by climate change and rapid urbanization and improve residents' quality of life.

Table 2. Definition of Smart City in recent 10 years (Albino, et al., 2015)

Definition of Smart City	Authors
Smart city as a high-tech intensive and advanced city that connects people, information and city elements using new technologies in order to create a sustainable, greener city, competitive and innovative commerce, and an increased life quality	Bakıcı et al. (2012)
Being a smart city means using all available technology and resources in an intelligent and coordinated manner to develop urban centers that are at once integrated, habitable, and sustainable.	Barrionuevo et al. (2012)
A city is smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance.	Caragliu et al. (2011)
Two main streams of research ideas: 1) smart cities should do everything related to governance and economy using new thinking paradigms and 2) smart cities are all about networks of sensors, smart devices, real-time data, and ICT integration in every aspect of human life.	Cretu (2012)
A smart city is based on intelligent exchanges of information that flow between its many different subsystems. This flow of information is analyzed and translated into citizen and commercial services. The city will act on this information flow to make its wider ecosystem more resource efficient and sustainable. The information exchange is based on a smart governance operating framework designed to make cities sustainable.	Gartner (2011)
Smart city [refers to] a local entity - a district, city, region or small country - which takes a holistic approach to employ[ing] information technologies with real-time analysis that encourages sustainable economic development.	IDA (2012)
Smart Cities initiatives try to improve urban performance by using data, information and information technologies (IT) to provide more efficient services to citizens, to monitor and optimize existing infrastructure, to increase collaboration among different economic actors, and to encourage innovative business models in both the private and public sectors.	Marsal-Llacuna et al. (2014)

Likewise, Ismagilova et al. (2019) has defined smart city as a city that actively adopts information and communication technologies to improve the quality of life for its residents in terms of economy, traffic, environment, and interaction with government. Bakıcı et al. (2012) also described the smart city as a sustainable, environmental, and high-tech city that improves citizens' quality of life by connecting people, information, and urban elements.

2) Necessity and mandatory requirement

It is necessary to think about why so many countries and institutions have paid attention to smart city projects. As explained in the previous chapter, about 75 percent of GHG that causes climate change is emitted from cities. In addition, the rapid population growth and urbanization required more energy use, which exacerbates climate change and threatens human life in the form of droughts and floods. It, therefore, is necessary to find solutions in cities, the biggest cause of global warming. The solution should be made by considering energy, food, and water, which are the fundamentals of human life. Cities must be able to provide resources such as water and electricity that can be reliably used by the growing population, while reducing total energy consumption to decrease carbon emissions that cause global warming. The concept of urban development proposed to achieve this goal is a smart city. I believe that the essential elements to become the smart city are in the Six Milestones presented previous chapter (Fig 5). These include expanding the use of renewable energy, changing transportation and industrial structure to reduce carbon emissions, and environmentally friendly forest restoration. This means that the introduction of new industrial forms and lifestyle is necessary. As a result, various forms of smart cities that combine many technologies and policies are being developed throughout the world.

Data is the most important keyword for being smart city. All elements of the city are connected by ICT (Fig 24), and all actions and processes appearing in life are produced, accumulated, and analyzed in data format. These data are the basis for future prediction and decision making after analysis. These decisions are not just for managers like the government. All analyzed data in shared in real time to citizens, which is the basis for determining their actions. Through real-time traffic check, departure time and means of transportation can be selected, and real-time response such as reduction of usage by checking amount of water consumption, water quality, and accident status can be made. Bristol city in England is a good example city to meet this smart city concept. The city launched the smart city project in 2021. They defined smart city as "city associated with the application of data and technology to increase efficiency, minimize costs and enhance convenience". Under the framework of Smart Energy, Smart Transport and Smart Data, Bristol city established a platform called "Open Data Bristol (Fig 25)" to build and share most of the data gathered from citizen's daily life and operation of city. These efforts saved about 20 percent of energy use over 15 years, from 2005 to 2020 (Bristol City, n.d., USE, n.d.). In addition, Bristol City set the strategy called "One City Climate Strategy" to be carbon neutral and climate resilient by 2030 in 2020 through their smart city performance (Bristol City, 2020).

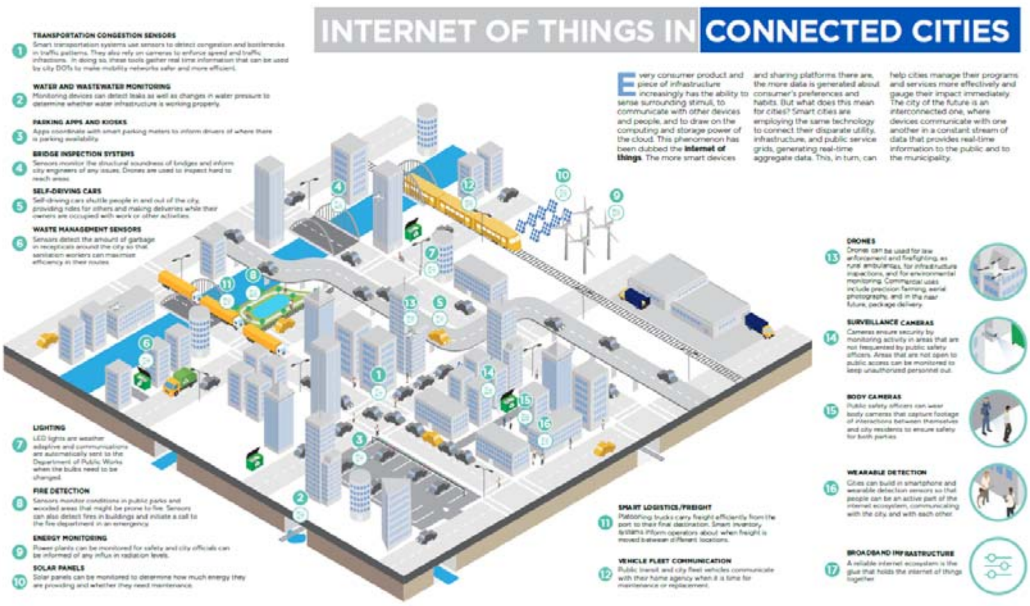


Fig 24. Connected Cities (National League of Cities, 2016)

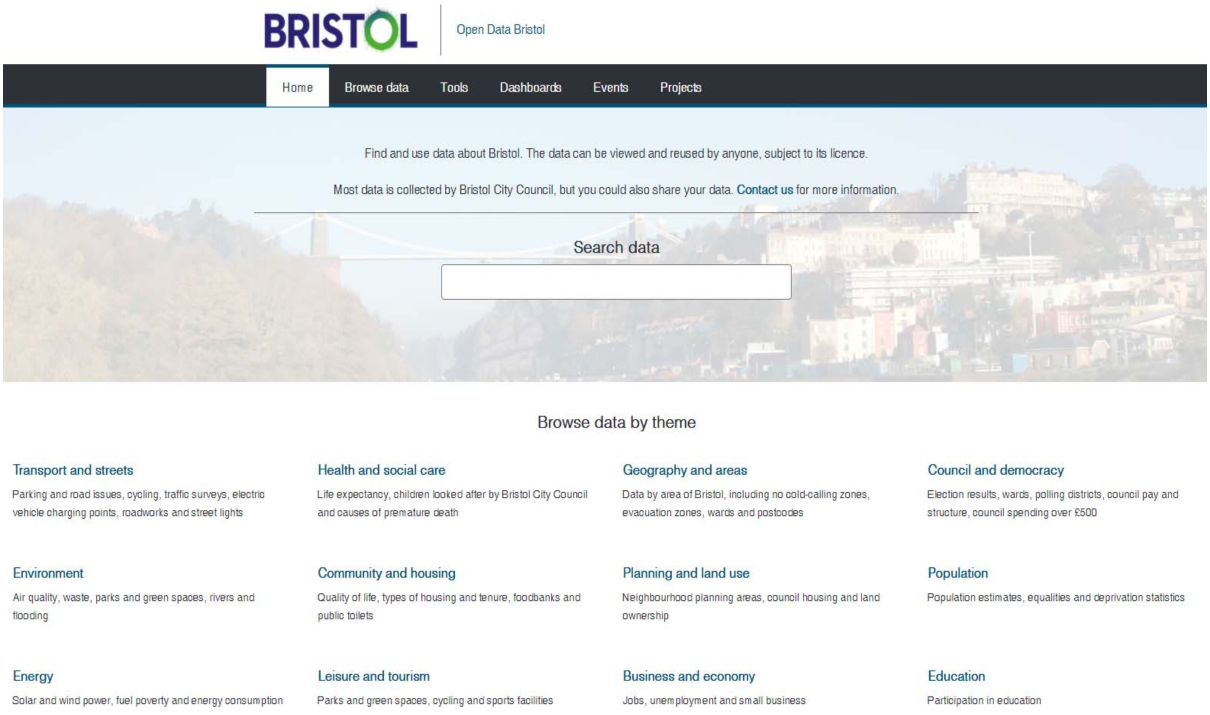


Fig 25. Open Data Bristol (Bristol, n.d.)

3) The development phase of smart city in Korea

According to KRIHS (2018), the development of smart cities in Korea have been carried out in three phases (Table 3). That is construction, connecting and enhancement stages. This division is a step-by-step approach that takes into account changes in national policy, internal and external environments, and the current status of each period considering economic power. There is one thing that I want to stress here. Many projects related to smart cities were completed and underway. It, however, is not easy to find successful projects among them. I think one of reason for this is that the reality of country or cities, that is, the technologies base, the level of the established facilities and infrastructure, and the financial capacity, have not been sufficiently taken into account. This step-by-step development status of Korea can be a reference strategy for all future smart city development projects.

Table 3. Characteristics of smart cities in Korea, by stage (KRIHS, 2018; OECD, 2020)

	Construction (2003~2013)	Connecting (2014~2016)	Enhancement (2017~)
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	Law of Ubiquitous City Construction	Law of Ubiquitous City Construction	Law for Smart City Creation and Promotion of Industries
Main agents	Ministry of Land, Infrastructure, and Transport	Ministry of Land, Infrastructure, and Transport; Ministry of Science and ICT; Ministry of Trade, Industry and Energy	Smart city governance
Target	New towns	New towns, existing cities	New towns, existing cities, declining cities
Projects	Integrated Operation Control Centre (IOCC), 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

4) Status of smart city development

According to Research and Markets (2020), “The global smart cities market size is expected to grow from USD 410.8 billion in 2020 to USD 820.7 billion by 2025, at a Compound Annual Growth Rate (CAGR) of 14.8 percent during the forecast period”. ReportLinker (2020) is also expected the global market of smart cities will be a USD 3 trillion by 2027, at a CAGR of 22.5 percent. Although there are some numerical differences between issuing institutions, there are no different opinions on the large market size and growth potential.

In order to lead this market, many countries around the world are conducting various smart city project. The Korean government has established “The third Smart City Comprehensive Plan” to create a development environment such as readjustment of related laws and technology development, and at the same time, about 23 smart city projects including two national pilot projects are being carried out through cooperation with private sector (MOLIT, 2019; Smart City Korea, n.d.). Among them, Busan Eco Delta City is building an environment-friendly water-circulation type city that combines the technology of the fourth industrial revolution by utilizing the characteristics of the waterfront city well.

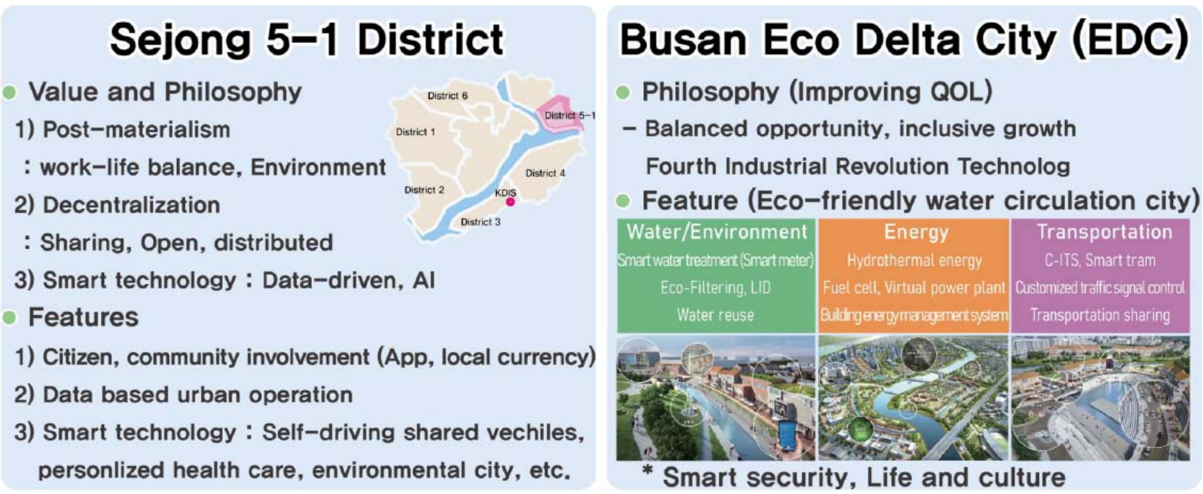


Fig 26. National smart city pilot project in Korea (Author using source Smart City Korea, n.d.)

Both developed and developing countries are strategically promoting smart cities. Developed countries provide various solutions through cooperation with public sectors to solve urban problems, and developing countries are pushing to strengthen their national competitiveness. In the case of Singapore, which was described earlier, Smart Nation, not just a city, was presented as a national vision. Likewise, there are very large investments in smart cities worldwide.

Fig 27. Investment scale of smart city (MOLIT, 2019)

International cooperation to develop smart city projects is also actively underway. Representative cooperation is the ASEAN Smart City Network, hereinafter ASCN. ASCN is a platform for promoting smart city projects in ASEAN countries.

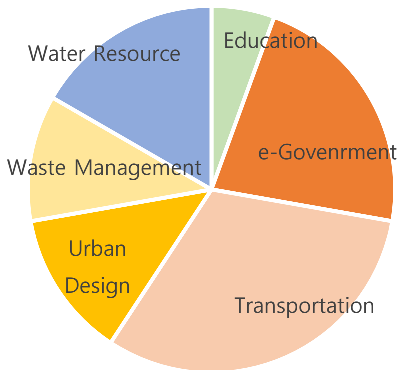


Fig 28. The project of ASCN (ASCN, 2018)

Its establishment proposal was approved at the 32nd ASEAN summit on 28 April 2018. A lot of parties such as government and companies from ASEAN countries and Korea, China, Japan, and the United States are working together to develop the project. The purpose of

ASCN is that first, they facilitate cooperation on smart cities development. Second is to catalyze bankable projects with the private sector. Third is to secure funding and support from ASEAN's external partners. Through this platform, ASCN, a total of 53 projects was presented as priority project from 26 cities across all ten ASEAN countries. The ranking of types of projects is in order of transportation, e-Government and Water resources. The results are seen as reflecting the issue ASEAN countries face at now. Main issues listed here are traffic congestion, information management for decision making, securing water resources against climate change (Ministry of Foreign Affairs in Singapore, 2019; ASCN, 2018). Another cooperation platform is "2020 K-City Network: Global Cooperation Program", which is under the leadership of the Korean government. The program began in 2020 with a project cost of about 0.85 million USD, developing smart city projects in target countries through cooperation with the Korean government. 12 candidate projects currently have been selected and the project is being carried out through the establishment of various cooperative relationships (MOLIT, 2020).

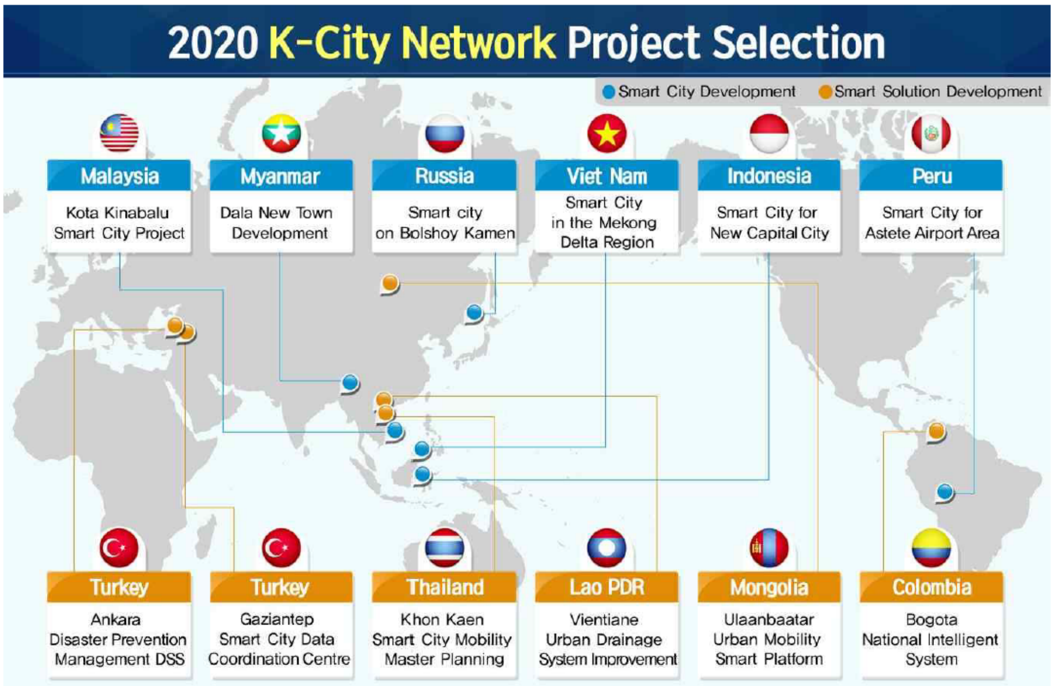


Fig 29. 2020 K-City Network's target countries and projects (MOLIT, 2020)

5) Smart city in terms of water management

So far, I have reviewed the general status of smart city to respond to climate change and improve the quality of life. In this chapter, I will focus more on water management and describe in more detail what smart city need to have and what projects they need.

When it comes to water management, it is floods and droughts that are most affected by climate change. As explained in the previous chapter, the frequency and intensity of floods and drought are increasing, making it more difficult to provided stable water supply and disaster management. In addition, the rapid growth in population will require a lot of food production. This means that the supply of water and the resulting energy use will increase to secure the required water. In other words, available water resources are decreasing, while demand is increasing. Smart cities, therefore, in the future should have the goal of reducing energy use in preparation for climate change and at the same time providing sufficient water. And I want to add one keyword here as a function of smart city. It is convenience. Managers such as the government should be able to make decisions easily by various information, and to facilitate supply through smart technologies. Users should also be able to easily get clean water from anywhere and easily determine their consumption patterns through the various information shared by government. I believe, therefore, that in terms of water management, smart city should have the ability to reduce energy use while managing and supplying water with sufficient stability and convenience. Specific functions of smart city are as follow.

a. Supplying sufficient water for living, industry, and food production

b. Saving energy consumption and for securing additional water energy

c. Preventing water and energy related to water disaster: flood, drought, etc.

d. Rising quality of life

As a way to achieve these goals and functions as the smart city, we can consider supply expansion, efficiency improvement, and demand management. From now on, I will explain the outline of each way and the characteristics.

First, supply expansion is a way to secure additional water resources in consideration of the era of water stress, which is prolonged by drought. Among these methods to get water resources, reclaimed and desalination water are the most popular means. In order to prepare for drought, the development of large-scale dams can cause other environmental problems and many civil complaints. Securing alternative water resources, therefore, is now essential. This becomes even more evident when looking at the case studies of Singapore and Israel presented literature review. According to Seawater Desalination (n.d.), more than 120 countries are operating desalination plant. While this facility in the past was mainly operated in Middle East countries with many desert regions, it is spreading all over the world to secure resilience over climate change. Water reuse market is also expected to increase continuously (Zion, n.d.). This reclaimed water is expected to be expanded in the future in that we can secure additional ware resources through resource recycling in the situation where we live in a water shortage condition, and energy can be saved through this.

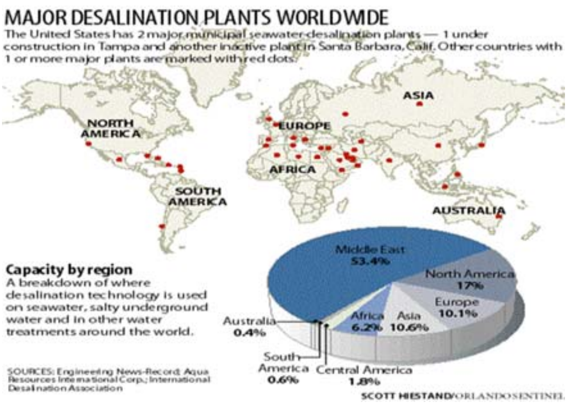


Fig 30. Major desalination plants worldwide (Seawater Desalination, n.d.)

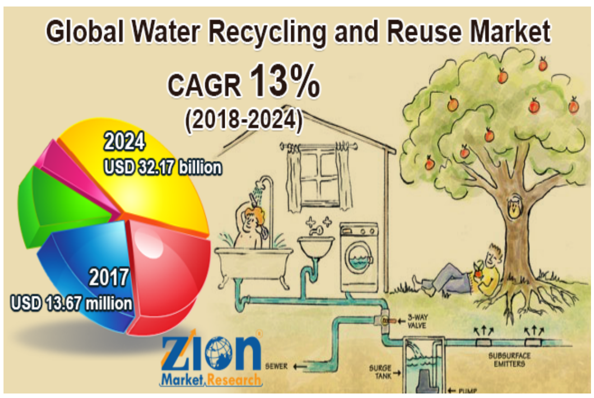


Fig 31. Water recycling market (Zion, n.d.)

Although desalination and reclaimed water have still some challenges to be actively adopted due to their relatively high cost and high technologies, from a long-term perspective, the review and adoption of these alternative water resources plants with ICT is necessary for sustainable growth and stable water supply when planning for the smart city.

Second is efficiency improvement. A significant portion of the water is lost due to evaporation during transportation for irrigation and leakage of pipe in the city. This phenomenon is due in large part to existing centralized water management method as described above (Fig 32). In the centralized water management system, water is taken from water sources like river, and passed through a water purification plant located outside the city, and sent to the user though a long pipe. As explained in the literature review, this system requires long-distance water transport from intake to water supply, and a lot of losses occur in this process. It also takes a lot of energy, and the impact on the lower area in the event of an accident happens. The application of decentralized technologies, therefore, is required in smart cities that will be planned in the future.

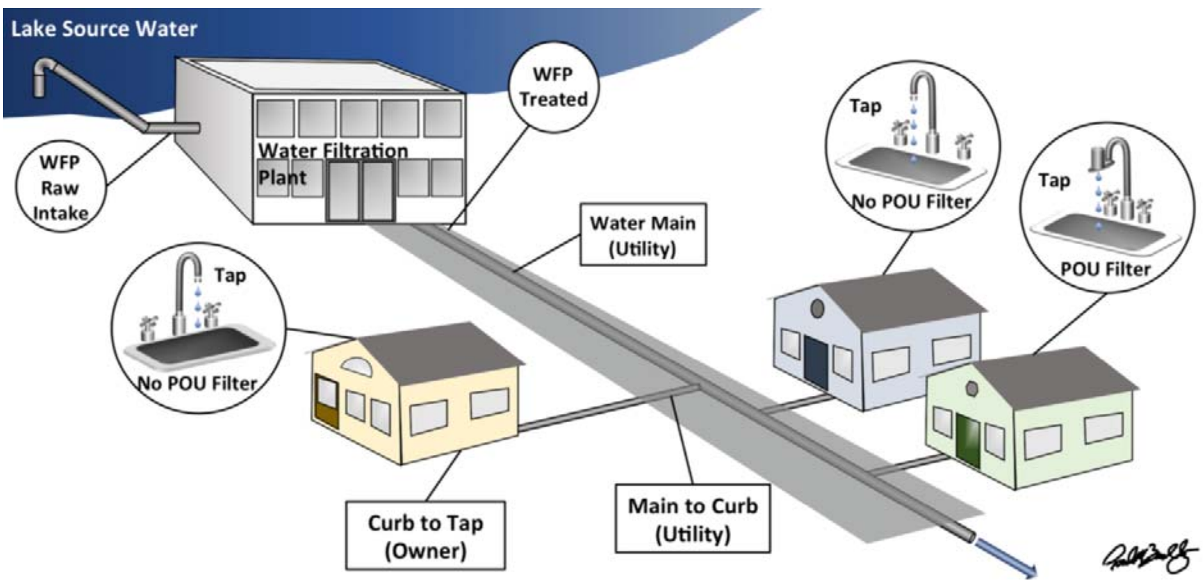


Fig 32. Concentrated water distribution system (USGS, 2015)

Decentralized water management system is to be carried out through small-scale facilities in the region, away from the management through large-scale concentrated plants. Representative technologies for decentralized water management include low impact development, LID, smart meter, decentralized water purification facilities and deep stormwater storage-drainage facility, etc. Among them, LID is that "to systems and practices that use or mimic natural processes that result in the infiltration, evapotranspiration or use of stormwater in order to protect water quality and associated aquatic habitat (EPA, n.d.)". In other words, it is a rainfall management technique that works through storage and infiltration from rainfall points and is a method that is widely applied worldwide for eco-friendly water management (Shin, et al., 2018). The installation of various storage and infiltration facilities in the region can achieve effects such as mitigating flood effects, reducing non-point pollution, securing groundwater, and creating waterfront spaces.

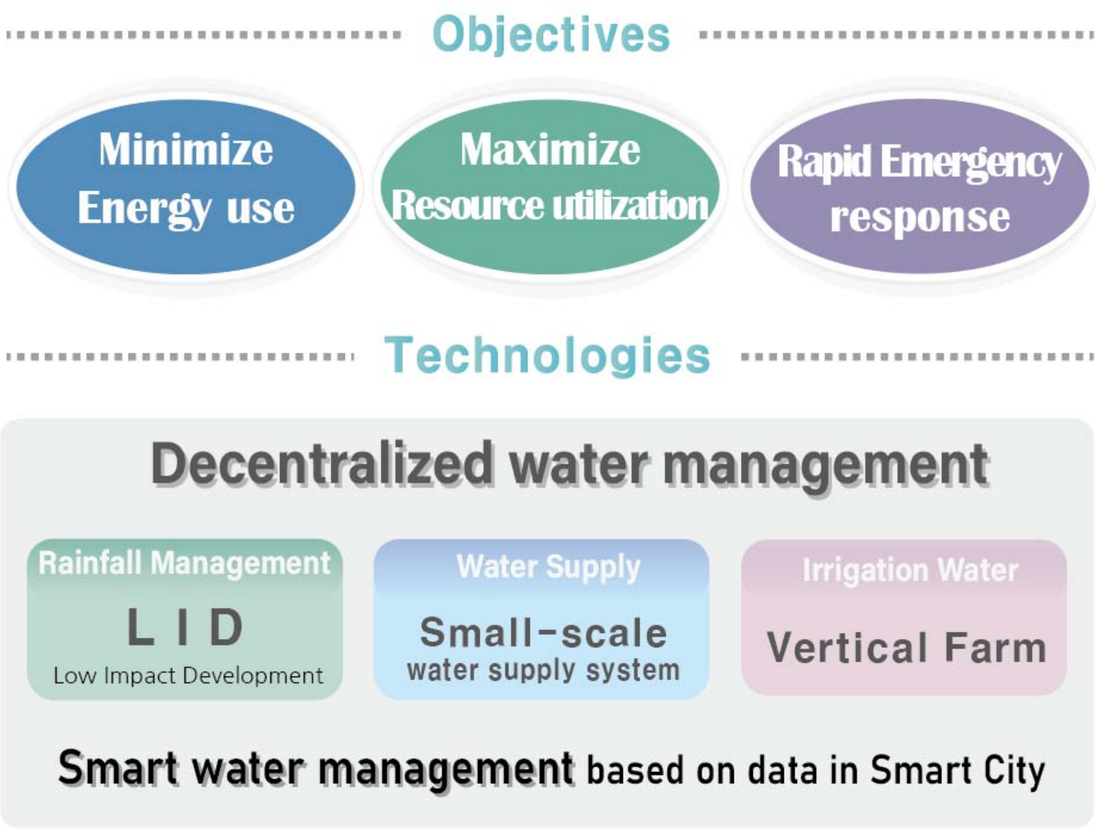


Fig 33. Decentralized water management technologies

Second is smart meter technology. Smart meter is a system that can transfer real-time data remotely by using wireless communication devices. Real-time data such as flow rate, pressure, and water quality in transfer pipe can be gathered, and it can enable immediate response when accidents like leakage of pipes or water pollution occur. In addition, when such a smart meter system is applied, the entire city is usually composed of several sub-region (blocks). This is because it is easy to analyze data by region when building a block system, and it has the advantage of being able to respond and recover urgently to only small sub-region in case of emergency situations. So, this can also be seen as a kind of distributed water management technology. Moreover, a vertical factory-type water treatment system has recently been developed (KAIA, n.d.). This is also a distributed installation on a small scale away from the existing large-scale water purification plant system and has the advantage of minimizing energy waste by using renewable energy such as solar power generation, and actively coping with urgent demand changes.

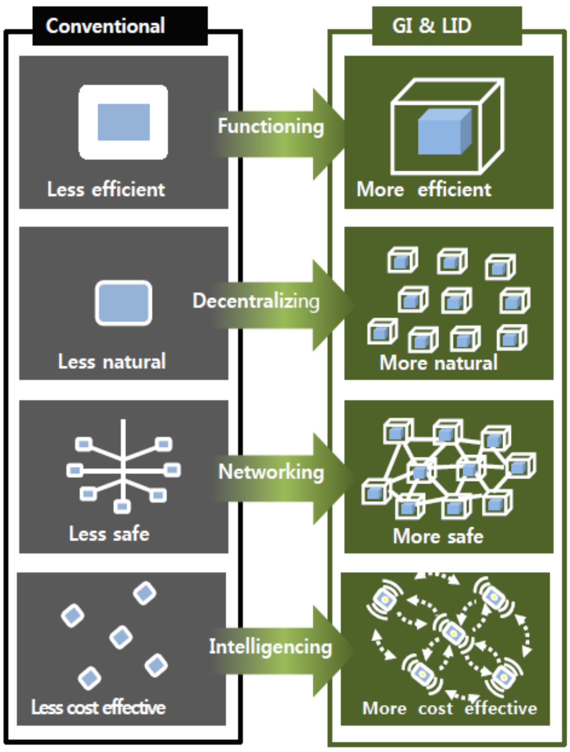


Fig 35. Comparison of conventional and LID technology concept (Shin, et al., 2018)

Fig 34. Smart water meter diagram (Lakewood Water District, n.d.)

Fig 36. Vertical water treatment system model (KAIA, n.d.)

The additional technology I would like to introduce as another decentralized water management technology is vertical farming. Currently, about 70 percentage of freshwater is used for agriculture (Khokhar, 2017). More important, therefore, that securing additional water is efficient water management in the agriculture sector. This usage is expected to increase further along with population growth in the future. So, vertical farming method has been developed to solve these problems. Leblanc (2020) defined vertical farming as “the practice of producing food on vertically inclined surfaces. Instead of farming vegetables and other foods on a single level, such as in a field or a greenhouse, this method produces foods in vertically stacked layers commonly integrated into other structures like a skyscraper, shipping container or repurposed warehouse”. These structural features facilitate the multi-use and recycling of irrigation water in the vertical farm (Fig 33). Through this process, IFarm argues that generally vertical faming saves 95 percent water compared with traditional farming (IFarm, n.d.).

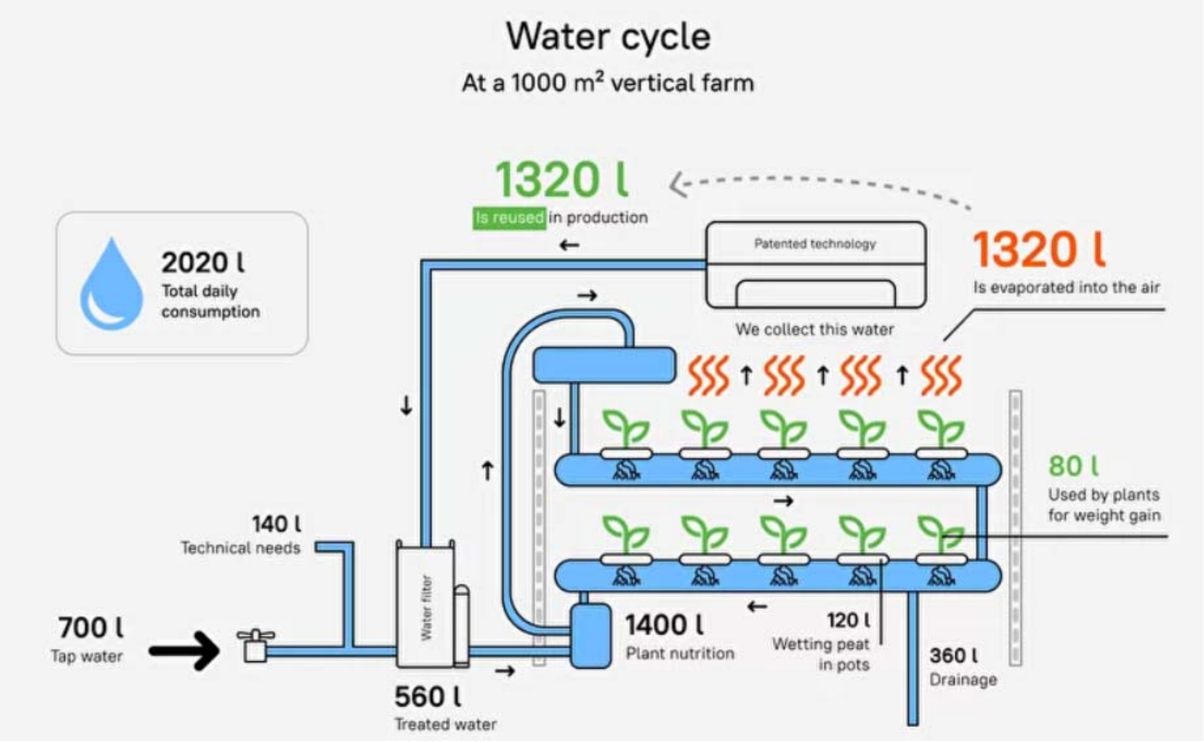


Fig 37. Water cycle in vertical farm (IFarm, n.d.)

Vertical farm is no longer technology that can be only seen in lavatory. We can see various kinds of vertical farm in anywhere.

Fig 38. Vertical Farm in local grocery market

The last is demand management. Demand management is essential when considering limited resources. Compulsory demand management, however, makes it difficult to ensure continuity of performance. It, therefore, is necessary to technically support voluntary demand management methods more easily. From this point of view, the information sharing service linked to the smart metering introduced in the previous chapter can be seen as an efficient method. The figure below (Fig 34) shows the service contents for each alarming commodity of EPAL, a Portuguese water company. It is structured so that users can easily receive actual use data from smart meter devices installed in all homes through various media. There, however, are difference in the time interval and types of data shared depending on the price. If such systems are well-equipped and individuals can know their own water use patterns in real time, demand management will be a little easier.

FEATURES

WHAT YOU CAN DO	waterbeep home	waterbeep plus	waterbeep pro	waterbeep premium	waterbeep local
Check the billed water consumption in recent months	✓	✓	✓	✓	✓
Discover the average daily consumption per person and compare it with the typical Lisbon figures	✓	✓			
Meter reading	Read by the Customer, with online validation	Read automatically via telemetry	Read automatically via telemetry	Read automatically via telemetry	Read automatically via telemetry
Graphically track the evolution of readings made in the last 30 days	✓				

Fig 39. Type of smart water metering service (EPAL, n.d.)

So far, in terms of water management, I have reviewed the conditions and measures to be included in smart city. What is more important here, however, is that all the methods and functions presented above should be managed in an integrated manner. As previously discussed in WEF NEXUS, water management is not just for water supply and flood prevention. This is because food production, energy supply and demand, population and industry status are all closely related. So, it is necessary to establish the basis for comprehensive review by connecting all functions and infrastructures with ICT in the city. The collected data from all in the city should be analyzed in real time for city operation, policy decision, and water management. And the analyzed data should be transparently shared with citizens again. In addition, all water management techniques must take into account the water circulation system. All processes of the water cycle, from the point of rainfall occurrence to storage and infiltration, water use and reuse, and evaporation, must be systematically organized and operated. As an implementation technology for this, there is a smart water grid method that builds and manages all elements as a network. The core of smart water grid technology is to utilize ICT to effectively manage supply chains that lead to water supply – water distribution – water recycling and wastewater treatment as a representative technology for effective utilization of water resources and. Through this, the government aims to improve the efficiency of water resources and water supply systems and to develop them into ICT based next-generation water resource management systems for full-cycle integrated management (ME & KEITI, 2017).

In preparation for climate change, various technologies, and projects to achieve the objectives and functions of smart cities were presented as follow (Fig 40).

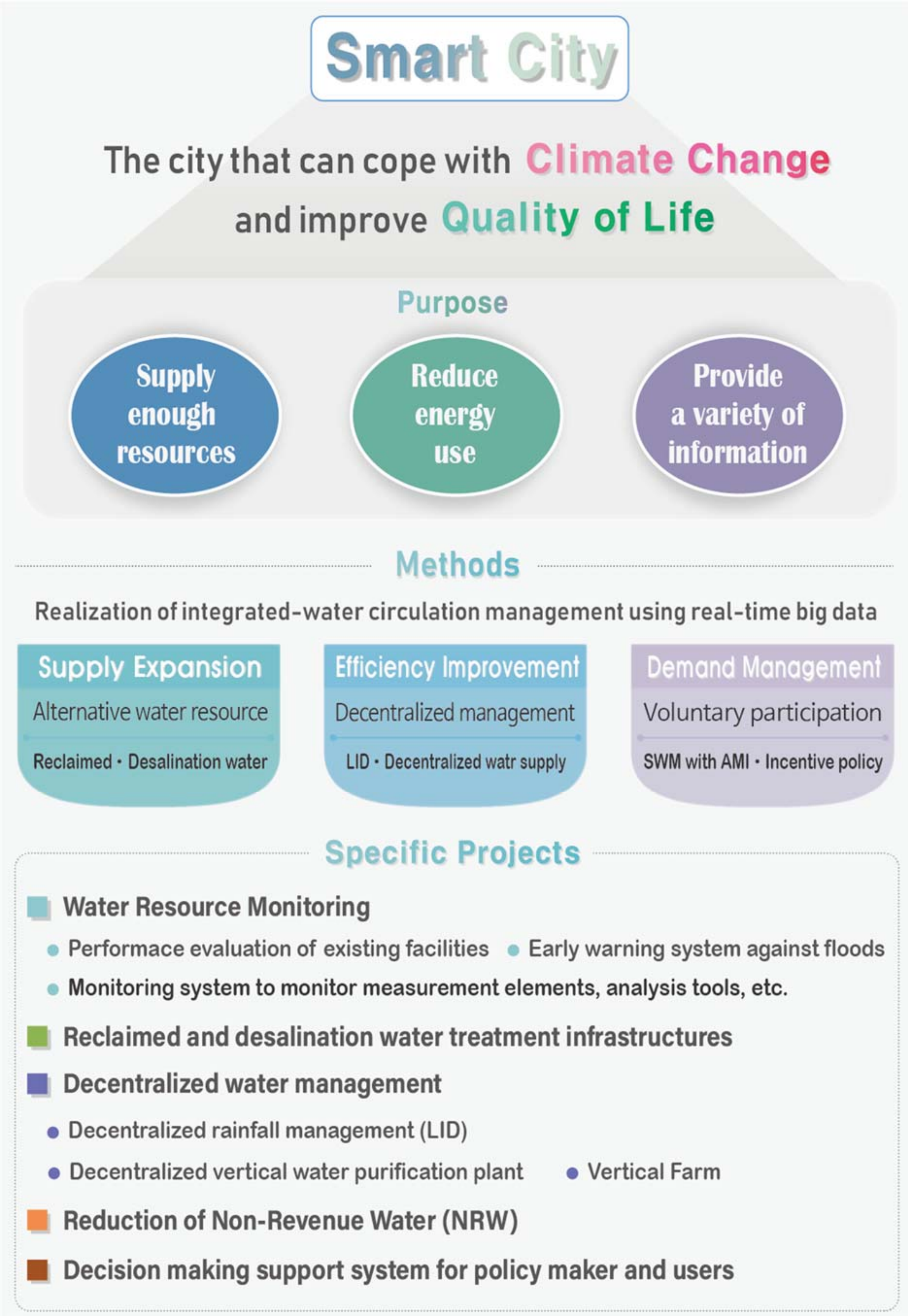


Fig 40. Components of being Smart City in terms of water management

Ⅳ. Action Plan

In this chapter, I review the execution strategies for actual commercialization of the previously reviewed items. In particular, the explosively increasing overseas smart city market is set as the main target and the implementation strategy is reviewed.

A. Goals in stage

So far, many technologies for water management in smart cities have been suggested. there, however, is a problem in applying all these things from the beginning in overseas business. When too good technology is put into many areas at once, project development has been faced often difficulty from the beginning due to excessive costs. It, therefore, is important to set goals for each stage in consideration of the economic power and infrastructure level of the target country. Here, the goal is set based on energy saving, which is the purpose of creating the smart city, and data management, which is the main means. Furthermore, I set the project goals for each stage by referring to the three steps presented by KRIHS (2018), construction, connecting, and enhancement.

Table 4. Development goal in terms of energy saving and data management at stage

Stage	Energy saving	Data management
First	Understanding energy use status	Installation of data measurement facilities / Secure of accessible data
Second	Energy saving city	Analysis using measured data / Automatic detection (pipe leakage, etc.) / One-way communication (various information: flood warning, the amount of water use, etc.)
Third	Net-Zero Energy City [Every energy being used in city can be generated from renewable energy source in that city]	All information can be disseminated to citizen / Bidirectional communication (citizens take participated in decision making process)

B. Necessary technologies related water management by development stage

1) First stage

a. Expected projects

a) Goal: data acquisition for establishing smart management system

b) Definition: Secure data for pilot project area and evaluate existing facilities performance with small capital for developing new projects

c) Target area: Small pilot area at initial stage, existing aged facilities, etc.

d) projects

Water Security	Flood Management		Water works	
Water resources monitoring / Water resources security	Early warning system	Flood prevention facility	Smart water management	NRW (Non-revenue water)
□ Evaluation on stability or applicability of existing water resources facility - Measurement sensor, etc. - Water facility like dam □ Installation of new monitoring system - Sensor (rainfall, water level, water quality, etc.) - Monitoring center □ Training program for user	□ Evaluation on stability or applicability of existing water related disaster prevention facility - Measurement sensor, etc. - Flood prevention system like warning equipment, etc. □ Installation of new monitoring system - Sensor (rainfall, water level, water quality, etc.) - Monitoring center □ Training program for user		□ Installation or supplement of monitoring system about existing facilities	□ Evaluation on status - Existing facility Operation using sensor - The rate of NRW - The goal of NRW □ Installation or supplement of measuring system to water leakage, etc.

b. Action plan by related agencies

a) Goal: Finding and developing pilot project

b) Step-by-step work

Step	Korea (K-water, etc.)	Target countries	Fund-Agencies
□ Discussion with target countries - Promoting comprehensive cooperation - Signing MoU, etc.	□ Collecting project information of target countries - items: policies, bidding projects, future development plan, etc. - ways: branch office, web information, human resources, etc.	□ Propose cooperation ways to Korea - Comprehensive cooperation ways like infrastructure projects or training course, etc.	

Step	Korea (K-water, etc.)	Target countries	Fund-Agencies
□ Making budget for engineering service for pilot project - ODA (Grant, loan, etc.) - Financial funds of target country	□ Rough review to determine whether projects should proceed or not - existing relevant document review □ Proposal of cooperation project to target countries - discussion with fundraising methods, etc. □ Application of ODA candidate project for implementing engineering service to ODA agencies such as government, KOICA, K-EXIM, etc.	□ (1st option) Making budget using owned financial funds □ (2nd option) Making concept paper for application of ODA candidate project	□ (1st option) financial funds owned by target countries □ (2nd option) ODA funds [ODA agencies] - Grant: Government, KOICA - Loan: K-Exim, MDB (WB, ADB, IDB, etc.)
□ Engineering service for project feasibility review - Master plan for comprehensive project discovering * Action plan: short-long-term plans - Feasibility study for evaluation feasibility for certain project * priority project proposed by master plan	□ Selection of contractor □ Performance management of engineering service - Suggestion of candidate project list - Evaluation of project's feasibility	□ Implementation support of engineering works □ Cooperation work to find pilot projects	□ Review performance
□ Discussion of pilot project development ways with target countries - Project range - Ways to fundraise project costs for construction □ Making budget for construction of pilot project	□ Proposal of project's implementation plan in detail - (Project description) target project, projects areas and range, step-by-step action plan, etc. * project expansion plan (pilot -> main body, etc.) - (Fundraising methods) ODA or financial funds * ODA, financial funds, matching funds, etc.	□ Discussion detail action plan with Korea □ Making budget - Financial funds or ODA or matching funds, etc.	□ Matching funds - Combination of financial funds, grant and loan, etc. □ Reviewing of feasibility for loan
□ Engineering service - Basic and detail design focusing H/W, etc. □ Construction and mobilization □ User training	□ Performance management □ Making and implementation of training course for system users	□ Performance management □ Support of project implementation □ Mobilization and operation of system/facilities	□ Performance management
□ Monitoring of project effect - Gathering and management of data - Dissemination of project performance □ Discussion the ways to expand project range	□ Monitoring of project performance - Project effect, technical assistance □ Discussion with target countries - Follow-up project execution plans	□ Monitoring of project effect - Analysis the effect caused by pilot project □ Discussion with Korea - Follow-up project execution plans - Advanced methods for improving project performance	

2) Second stage

a. Expected projects

a) Goal: data analysis for utilizing smart management system

b) Definition: Embedded with early-stage data analysis system for pilot project area, expansion of project area

c) Target area: Project area expansion

d) projects

Water Security	Flood Management		Water works	
Water resources monitoring / Water resources security	Early warning system	Flood prevention facility	Smart water management	NRW (Non-revenue water)
□ Analysis system - Adoption level: hydraulic and hydrology analysis using current and historical data - (Monitoring) river level, runoff quantity, etc. - (Security) driven water shortage year from water balance analysis □ Monitoring system for expanded target area - Sensor (quantity, quality, etc.) - User training □ Evaluation and revision of related standard	□ Installation of early warning system - Analysis data from monitoring site - River level and velocity, inundation areas, etc. □ Evaluation and revision of related standard	□ Construction of flood prevention facilities - Engineering: design, etc. - Reservoir, levee, etc. □ Construction - Planner, supervisor, technical assistance, etc. □ Assessment - Flood prevention capacity	□ Engineering: plans to increase water supply capacity - Analysis future demand quantity and present supply capacity - New infra-development plan (design, etc.) □ Construction of water supply infrastructure - treatment plant, pipe, etc.	□ Engineering: plans to decrease NRW - Investigate current supply network and leakage status - Establishment of target goal □ Implementation of plan - Establishment of BL system - Real time monitoring about pressure in pipe, etc.

b. Action plan by related agencies

a) Goal: Project expansion including S/W functions

b) Step-by-step work

Step	Korea (K-water, etc.)	Target countries	Fund-Agencies
□ Review action plan made by 1st stage - check appropriate reflecting pilot-project's performance (1st stage) - Modification of action plan as needed	□ Discussion project implementation plan with target countries - Evaluation methods of 1st project performance - Follow-up project plans, etc.	□ Discussion project implementation plan with Korea - Evaluation of 1st project performance - Follow-up project plans, etc.	
□ Installation of S/W (analysis) functions to system [If budget is available, this step can be included 1st stage] - Engineering: plan, review and analysis items, cost considering economic status of target countries - Installation of analysis system - Analysis for target area (1st stage project area) * hydraulic, hydrology analysis for monitoring and warning	□ Engineering: basic, detail design - Technologies level to be applied system, project cost, etc. □ Installation analysis system - Including technical assistance such as establishing input data, etc. - User training	□ Making budget for project - ODA or financial funds □ Operation of analysis system - Establishment and analysis of model for identifying water resources status	□ Matching funds - Combination of financial funds, grant and loan, etc. □ Reviewing of feasibility for loan
□ Making decision to expand project area - Expanding project area based on the performance of the pilot project - Review main project plan in detail * project area, ways to fundraising cost, etc.	□ Proposal of follow-up project's implementation plan - (Fundraising methods) ODA or financial funds * ODA, financial funds, matching funds, etc. □ Engineering: feasibility study	□ Discussion detail action plan with Korea □ Making budget - Financial funds or ODA or matching funds, etc.	□ Matching funds - Combination of financial funds, grant and loan, etc. □ Reviewing of feasibility for loan
□ Engineering service - Basic and detail design, etc. □ Construction and mobilization □ User training	□ Performance management □ Making and implementation of training course for system users	□ Performance management □ Support of project implementation □ Mobilization and operation of system/facilities	□ Performance management
□ Monitoring of project effect - Gathering and management of data - Dissemination of project performance - Analysis using gathered data □ Discussion the ways to expand project range	□ Monitoring of project performance - Project effect, technical assistance □ Discussion with target countries - Follow-up project execution plans	□ Monitoring of project effect - Analysis the effect caused by pilot project □ Discussion with Korea - Follow-up project execution plans - Advanced methods for improving project performance	

3) Third stage

a. Expected projects

a) Goal: Dissemination and adoption of new kinds of technologies

b) Definition: Embedded with more advanced data analysis system for entire project area, enforcing of information sharing

c) Target area: Entire project area

d) projects

Water Security	Flood Management		Water works	
Water resources monitoring / Water resources security	Early warning system	Flood prevention facility	Smart water management	NRW (Non-revenue water)
□ Analysis system - Forecasting and decision-making system - (Monitoring) precipitation forecast - (Security) estimation of potential water resources in future □ Dissemination -Notice on online to citizen real-time water related information (river water level and quantity, drought status, suppliable quantity, quality etc.) □ Resources-Energy saving - (Alternative resources) water reuse, desalination, LID, etc. - (Energy) WEF NEXUS concept (net zero city, vertical farm, etc.)	□ Emergency action plan - establishment of criteria for issuing warning - emergency evacuation plan - MDFDA: Multi-dimensional flood disaster analysis □ Rainfall forecast model	□ Dissemination of relevant Information - The amount of rainfall, river water level, etc. □ Enhancement of flood prevention capacity through IWRM concept	□ Dissemination of relevant information - The amount of water consumption in house and fees in real-time □ Smart water grid - Water management in real time by using AMI	□ Dissemination of relevant information - Status: the amount of production and leakage of water □ Real-time leakage detection system

b. Action plan by related agencies

a) Goal: Enforcing S/W functions and adoption energy-resources saving technologies

b) Step-by-step work

Step	Korea (K-water, etc.)	Target countries	Fund-Agencies
□ Review action plan made by 2nd stage - check appropriate reflecting project's performance (2nd stage) - Modification of action plan as needed	□ Discussion project implementation plan with target countries - Evaluation methods of 1st project performance - Follow-up project plans, etc.	□ Discussion project implementation plan with Korea - Evaluation of 1st project performance - Follow-up project plans, etc.	

□ Review on the necessity of adoption energy-resources saving technologies	□ Engineering: Feasibility - Application of short and long-term water resources available plan through master plan's result	□ Engineering: cooperation works with Korea, etc.	
□ Enforcing of S/W (analysis) functions to system [If budget is available, this step can be included 2nd stage] - Enforcing items 1) forecast and decision making using analyzing data from daily lives 2) Dissemination of analyzed data to citizen - Installation of analysis and dissemination system - Analysis for target area (national area)	□ Engineering: basic, detail design - Technologies level to be applied system, project cost, etc. □ Installation analysis system - Including technical assistance such as establishing input data, etc. - User training	□ Making budget for project - ODA or financial funds □ Operation of analysis system - Establishment and analysis of model for identifying water resources status	□ Matching funds - Combination of financial funds, grant and loan, etc. □ Reviewing of feasibility for loan
□ Making decision to adopt energy-resources saving technologies - Target technologies: desalination, Reuse water, net-zero city, LID, vertical farm, etc. - Rough review * Reviewing the adequacy of project implementation considering the conditions of the target countries' condition: level of pre-installed infrastructure and economic status, etc.	□ Proposal of project's implementation plan - (Fundraising methods) ODA or financial funds * ODA, financial funds, matching funds, etc. □ Engineering: feasibility study	□ Discussion detail action plan with Korea □ Making budget - Financial funds or ODA or matching funds, etc.	□ Matching funds - Combination of financial funds, grant and loan, etc. □ Reviewing of feasibility for loan
□ Engineering - Feasibility study, basic, detail design, etc. □ Construction and mobilization □ User training	□ Performance management □ Making and implementation of training course for system users	□ Performance management □ Support of project implementation □ Mobilization and operation of system/facilities	□ Performance management
□ Monitoring of project effect - Gathering and management of data - Dissemination of project performance - Analysis using gathered data □ Discussion the ways to expand project range	□ Monitoring of project performance - Project effect, technical assistance □ Discussion with target countries - Follow-up project execution plans	□ Monitoring of project effect - Analysis the effect caused by pilot project □ Discussion with Korea - Follow-up project execution plans - Advanced methods for improving project performance	

Ⅴ. Conclusion

This is an era of climate crisis. As mentioned above, climate change is having a serious impact on Earth's hydrology condition. Even at this moment, many places are facing problems such as floods and droughts because of climate change. This can be seen as a small problems of water scarcity, but it is also a problem that depends on the survival of mankind, such as human right and inequality. For this reason, the international community is responding to this problem through various forms of cooperation and policies. In addition, many research results and technologies are being applied to the Green New Deal project. One of the representative projects of the Green New Deal is the development of smart city. The city is the largest emitter of GHG that causes the climate change, and since this city will continue to expand with sustained population growth, we must find a solution in the city. And the answer is the smart city. We should break away from the fossil fuel-based centralized energy management approach that is being applied to get energy used in cities. It is necessary to apply the decentralized management technologies based on renewable energy using solar and wind that is located anywhere in the city. Through this, we need to improve the quality of life for more people by using less energy. Smart city should be developed with this purpose.

In this paper, I introduced the current situation of the climate crisis and international efforts and technologies to cope with it. I also described the definition and purpose of smart cities, essential elements, and various technologies, focusing on water management. Finally, I presented an action plan to enter the overseas smart city development projects.

In this paper, however, the amount of carbon emission reduction by each technology could not be presented quantitatively. Efforts to classify technologies suitable for the status of the project site through quantitative comparison with the characteristics of each technology and the amount of carbon emission reduction will be required in the future.

I hope that those who develop and plan related smart city projects in the future will refer to this paper and apply it to actual projects.

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