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Abstract	The aim of this report is to identify improvement options to further enhance the sustainable management of water resources in each of the POWER Key Demonstration Cities (KDCs), namely Leicester, Milton Keynes, Sabadell and Jerusalem. These improvement options arise from the challenges that are identified using the City Blueprint approach. This is a diagnosis tool which reveals where a city's strong and weak points lie and can serve as the key first step in strategic long-term planning to realise cities to be sustainable and water-wise. Following the challenges derived from the City Blueprint approach, where the KDCs score low, other cities in the world are examined that have a higher performance on these indicators and where, these cities apply so-called best practices. In this way, we may learn from other cities how to improve urban water management in the KDCs. Furthermore, it is examined what is needed to translate these improvement options to the KDCs.

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Executive Summary

Over half of the global population live in cities (UN, 2018). This is expected to increase substantially in the future. Urbanisation and climate change impacts put water resources under increasing pressure. Therefore, it is important that measures are implemented to transition towards water-wise cities. The aim of this report is to identify improvement options to further enhance the sustainable management of water resources in the four Key Demonstration Cities (KDCs) of the POWER project, namely Leicester (United Kingdom), Milton Keynes (United Kingdom), Sabadell (Spain) and Jerusalem (Israel).

The City Blueprint Performance Framework is applied to the four KDCs and provides an overview of the key challenges that may affect local water management in addressing water-related challenges in their city. The City Blueprint approach consists of 25 performance indicators that cover the urban water cycle and includes categories for water quality, solid waste, basic water services, waste water treatment, infrastructure, climate adaptation and governance. The geometric average of the 25 indicators is the Blue City Index which is, like the individual indicators, scored from 0 (low performance) to 10 (high performance). In total, 75 cities are assessed according to the City Blueprint approach. However, none of these cities are classified as being water-wise. A city is water-wise when it scores a high performance on all indicators (8-10 points), and is described as a city that applies full resource and energy recovery in their waste water treatment and solid waste treatment, fully integrates water into urban planning, has multi-functional and adaptive infrastructures, and local communities promote sustainable integrated decision-making and behaviour. Furthermore, a water-wise city is largely water self-sufficient, attractive, innovative and circular by applying multiple (de)centralised solutions (Koop & Van Leeuwen, 2015a).

To identify improvement options for the four KDCs, a selection strategy is applied. Based on the assessment of the 25 performance indicators of the City Blueprint, key challenges are selected based on the indicators that score a low performance (0-2 points). Following from the key challenges, improvement options are identified based on best practices, which are demonstrated by other cities that score an excellent performance on the City Blueprint indicators (8-10 points). The City Blueprints for 75 cities have already been assessed in detail in Deliverable 4.5. This study builds on these results by providing improvement options and illustrating opportunities for city-to-city learning.

Through this assessment, the following key challenges have been identified for the KDCs:

- Improving stormwater separation and increasing green space in *Leicester;*
- Improving nutrient and energy recovery in *Milton Keynes;*
- Improving solid waste recycled and enhancing solid waste energy recovered in *Jerusalem;*
- Strengthening public participation and minimising the average age sewer in *Sabadell;*

The results show that there are wide variations between the KDCs as well as other cities in the world that have been assessed using the City Blueprint approach. It is notable that most of the best practices that we have discussed in this report include developed, wealthy cities. However, developed cities also score a higher performance on the indicators most of the times in comparison to developing cities. The report shows that cities can learn from each other to strengthen their performances, and that there are specific cases to learn from as showed by the best practices. City-to-city learning may thus be an essential catalyser to improve water management of cities. If cities would share their experiences, knowledge and best practices it is theoretically possible that the Blue City Index reaches the maximum value of 10. Hence, what no single city has yet been able to achieve, is possible if the best practices of each city are selected. In that case it can be considered as a water-wise city. A water-wise city scores high on all the performance indicators of the City Blueprint. City-to-City learning can be further enhanced by online platforms such as the best practice repository which enables two-way communication flows and enable cities to share their experiences and best practices. Within the POWER project, DSPs have been developed which may form an important

contribution in the efforts of cities to become sufficiently water-wise and enable cities to face water-related challenges. The main topics addressed by the key demonstration cities through the POWER DSPs are:

- The DSP of Sabadell (Spain) about water quality of non-potable reuse of treated wastewater;
- The DSP of Leicester (United Kingdom) about flood risk management;
- The DSP of Milton Keynes (United Kingdom) about the reduction of drinking water consumption;
- The DSP of Jerusalem (Israel) about water conservation.

The topics addressed on the POWER DSPs are different than the challenges that are discussed in this report as these follow from the City Blueprint assessments. There are some challenges that might occur when translating the best practices to the KDCs as social, economic and environmental factors are not taken into account when comparing the cities. This might affect the feasibility of the improvement options and therefore we recommend that future research focuses further on comparing cities that have similar social, economic and environmental characteristics.

List of acronyms

BCI	Blue City Index
CBF	City Blueprint performance Framework
DSPs	Digital Social Platforms
EC	European Commission
EIP	European Innovation Partnerships
GENCAT	Generalitat de Catalunya
GHG	Green House Gases
HDSR	Hoogheemraadschap de Stichtse Rijnlanden (regional water authority)
IWRM	Integrated Water Resources Management
JIPR	Jerusalem Institute for Policy Research
KDCs	Key Demonstration Cities
LCC	Leicester City Council
ONS	Office for National Statistics
SDGs	Sustainable Development Goals
SGRI	Scandinavian Green Roof Institute
STW	Severn Trent Water
UGI	Urban Green Infrastructure
UHI	Urban Heat Island
UNDP	United Nations Developments Programme
UNDESA	United Nations Department of Economic and Social Affairs
UNEP	United Nations Environment Programme
WWT	Waste Water Treatment

1 Introduction

1.1 Urban water challenges

Over half of the global population live in cities and it is projected that by 2050 approximately 6.3 billion people will live in an urban area (UN Water, n.d.). As the global population grows, so do the demands for water for various uses including drinking and sanitation. At the same time, human activity and climate change are disrupting natural water cycles, putting freshwater ecosystems under pressure (UNEP, n.d.). Climate change, with higher average temperatures and changing precipitation patterns, combined with increasing competition for available water resources, may result in substantial increases in the number of people living under severe water stress (Ligtvoet et al., 2014). Water can thus pose a serious challenge to sustainable development, but when it is managed efficiently and equitably, “water can play and enabling role in strengthening the resilience of social, economic and environmental systems in a world that is rapidly changing” (UNDESA, n.d.). The importance of water-related challenges has been recognised as a central theme within the United Nations Developments Programme (UNDP), in particular within the Sustainable Development Goals (SDGs). The SDGs specify that goals related to sustainable (urban) water management can be achieved through the implementation of Integrated Water Resources Management (IWRM), which is about balancing the water requirements of society, the economy and the environment (UN Water, 2018). Measures thus need to be implemented to enable the sustainable management of water resources, while ensuring that cities are resilient to floods, droughts and the challenges of growing water scarcity.

The City Blueprint provides municipalities and regions with a practical and comprehensive framework to define steps towards realising a more sustainable and resilient water cycle in collaboration with key stakeholders (Koop & Van Leeuwen, 2017). Cities can benefit from the experiences of other cities. Learning alliances can be used to improve awareness, community involvement, governance, and accelerate the transformation towards water-wise cities (Koop & Van Leeuwen, 2015a). Water-wise management is a state in which all 25 City Blueprint indicators score a high performance. Accordingly, Koop & Van Leeuwen (2015) describe water-wise management as: “Cities that apply full resource and energy recovery in their wastewater treatment (WWT) and solid waste treatment, fully integrate water into urban planning, have multi-functional and adaptive infrastructures, and local communities that promote sustainable integrated decision-making and behaviour. Cities are largely water self-sufficient, attractive, and innovative and circular by applying multiple (de)centralised solutions” (Koop & Van Leeuwen, 2015a). In total, 75 cities are assessed according to the City Blueprint approach. However, none of these cities could be classified as being water-wise. When we combine all the best indicator scores we get an imaginary city that has an optimal water management performance. This imaginary city shows that the challenges can be addressed when cities exchange their existing knowledge, experiences and know-how. City-to-city learning may thus enhance the transition towards water-wise cities. Table 1 provides an overview of different levels towards water-wise management that has been identified based on City Blueprint assessments as reported in Deliverable 4.5.

Table 1 Identified levels of water-wise management in cities based on the City Blueprint assessments (Table adopted from Koop & Van Leeuwen, 2015a)

BCI	Categorisation of IWRM in cities
0 - 2	**Cities lacking basic water services** Access to potable drinking water of sufficient quality and access to sanitation facilities are insufficient. Typically, water pollution is high due to a lack of WWT. Solid waste production is relatively low but is only partially collected and, if collected, almost exclusively put in landfills. Water consumption is low but water system leakages are high due to serious infrastructure investment deficits. Basic water services cannot be expanded or improved due to rapid urbanisation. Improvements are hindered due to governance capacity and funding gaps.
2 – 4	**Wasteful cities** Basic water services are largely met but flood risk can be high and WWT is poorly covered. Often, only primary and a small portion of secondary WWT is applied, leading to large scale pollution. Water consumption and infrastructure leakages are high due to the lack of environmental awareness and infrastructure maintenance. Solid waste production is high and waste is almost completely dumped in landfills. Governance is reactive and community involvement is low.
4 – 6	**Water efficient cities** Cities implementing centralised, well-known, technological solutions to increase water efficiency and to control pollution. Secondary WWT coverage is high and the share of tertiary WWT is rising. Water efficient technologies are partially applied, infrastructure leakages are substantially reduced but water consumption is still high. Energy recovery from WWT is relatively high while nutrient recovery is limited. Both solid waste recycling and energy recovery are partially applied. These cities are often vulnerable to climate change, e.g. urban heat islands and drainage flooding, due to poor adaptation strategies, limited stormwater separation and low green surface ratios. Governance and community involvement have improved.
6 - 8	**Resource efficient and adaptive cities** WWT techniques to recover energy and nutrients are often applied. Solid waste recycling and energy recovery are largely covered, whereas solid waste production has not yet been reduced. Water efficient techniques are widely applied and water consumption has been reduced. Climate adaptation in urban planning is applied e.g. incorporation of green infrastructures and stormwater separation. Integrative, centralised and decentralised as well as long-term planning, community involvement, and sustainability initiatives are established to cope with limited resources and climate change.
8 - 10	**Water wise cities** There is no BCI-score that is within this category so far. These cities apply full resource and energy recovery in their WWT and solid waste treatment, fully integrate water into urban planning, have multi-functional and adaptive infrastructures, and local communities promote sustainable integrated decision making and behaviour. Cities are largely water self-sufficient, attractive, innovative and circular by applying multiple (de)centralised solutions.

Water-wise management may thus be achieved when cities share experiences and subsequently learn from each other, which will also be the focus of this report. Accordingly, this study aims to identify improvement options to further enhance the sustainable management of water resources in four KDCs: Leicester (United Kingdom), Milton Keynes (United Kingdom), Jerusalem (Israel) and Sabadell (Spain). To identify improvement options we first elaborate the key challenges for each of the key KDCs. This is based on the outcomes of the City Blueprint assessments as provided in Deliverable 4.5. Following from this, improvement options are identified that could strengthen these priorities based on the City Blueprint assessment of 75 cities that score high on the conditions in comparison to the KDCs (so-called best practices). In this way, the KDCs can learn from other cities in the world how to enhance their urban water management as the best practices can be used as a source of inspiration for local authorities.

This report is an output of the H2020 POWER project, which is a user-driven project that aims to share the knowledge of and experience on water scarcity, security, quality, and water consumption-related issues in different local authorities in the EU and beyond. Within the project, Digital Social Platforms (DSPs) have been developed which may form an important contribution in the efforts of cities to become sufficiently water-wise and enable cities to face these increasing water-related challenges. The identification and matching of improvement options and best practices that this study provides, is therefore an essential component of how the DSPs and, in particular, the shared database of best practices (i.e. the POWER best practices repository https://bestpractices.power-h2020.eu/) is designed to address.

1.2 Document outline

Following from this introduction, the selection strategy of the improvement options is explained in Section 2. The key challenges for water-wise management are based on the outcomes of the City Blueprint Performance Framework. This framework is thus explained in Section 2, whereas the key outcomes for each city are discussed in Sections 3, 4, 5 and 6. In these sections, we identify the improvement options for each of the KDCs based on best practices retrieved from cities that score a high performance on specific indicators of the City Blueprint. Moreover, it will be examined in these sections what is needed to translate these best practices to the KDCs. In Section 7, the potential role of the DSPs to improve urban water management is discussed. Finally, in section 8, the conclusions are provided.

2 Research method

For each of the KDCs, the key challenges for the water-wise management are based on the outcomes of the City Blueprint Performance Framework. In the following section this framework is presented and it explains how the framework leads to the selection of key challenges and best practices.

2.1 The City Blueprint Performance Framework

Table 2 provides an overview of the City Blueprint Performance Framework (CBF). The City Blueprint provides municipalities and regions with a practical and comprehensive framework to identify steps towards a more sustainable water management (Koop & Van Leeuwen, 2015a). The CBF consists of 25 performance indicators consisting of seven broad categories that cover various components of the urban water cycle, including: water quality, solid waste treatment, basic water services, waste water treatment, infrastructure, climate robustness and governance. The indicator scores range between 0 points (low performance) to 10 (excellent performance). The scoring is done by an interactive approach together with local stakeholders such as water utilities, city council, and research organisations. Each indicator consists of a calculation method, which is based on publicly available data. The final scores are subjected to a quality assurance in order to ensure a reproducible and reliable analysis. After scoring all the indicators of the City Blueprint, a radar chart of all indicators is provided. For a more detailed description of methodology reference is made to the European Innovation Partnerships (EIP) City Blueprint website (EC, 2015). The geometric average of all 25 indicators results in the Blue City Index (BCI). The BCI provides a first set of indicators of where the city is compared to other cities on their paths of becoming resilient.

Table 2 Overview of the City Blueprint® Framework (CBF; Koop & Van Leeuwen 2015a)

Goal	25 indicators divided over seven broad categories:	
Framework	**I Water quality**	1. Secondary WWT 2. Tertiary WWT 3. Groundwater quality
	II Solid waste treatment	4. Solid waste collected 5. Solid waste recycled 6. Solid waste energy recovered
	III Basic water services	7. Access to drinking water 8. Access to sanitation 9. Drinking water quality
	IV Wastewater treatment	10. Nutrient recovery 11. Energy recovery 12. Sewage sludge recycling 13. WWT energy efficiency
	V Infrastructure	14. Stormwater separation 15. Average age sewer 16. Water system leakages 17. Operation cost recovery
	VI Climate robustness	18. Green space 19. Climate adaptation 20. Drinking water consumption 21. Climate-robust buildings
	VII Governance	22. Management and action plans 23. Public participation 24. Water efficiency measures 25. Attractiveness
Data	Public data or data provided by the (waste)water utilities and cities based on a questionnaire (EIP Water 2017b)	
Scores	0 (low performance) to 10 (excellent performance)	
Overall score	Blue City Index® (BCI), the geometric mean of 25 indicators varying from 0 to 10	

2.2 Identifying key challenges and best practices

In order to identify improvement options for the four KDCs, a selection strategy is required. Based on the assessment of the 25 performance indicators, key challenges are selected based on indicators that score a low performance (0-2 points). For these priorities that need to be strengthened, improvement options are elaborated based on other cities in the world that score an excellent performance on the priority indicators (8-10 points). Desk research has been conducted to explain the improvement options found in the best practices. Scientific literature and policy documents provided information on various improvement options. Literature was retrieved through online databases such as Scopus (Elsevier, n.d.). The information provided on the best practices in this report can in the future also be used as input for the POWER Best Practices Repository. In this repository, promising concepts to tackle water-related challenges in the POWER cities are collected (https://bestpractices.power-h2020.eu/).

3 Improvement options for sustainable urban water management in Leicester

This chapter provides an overview of the challenges that Leicester faces regarding sustainable urban water management. Based on the key challenges provided by the CBF, improvement options for Leicester are provided based on best practices. Furthermore, it examines what is needed to translate these improvement options to Leicester.

3.1 Overview of key challenges

Leicester is the largest city in the East Midlands with a population of more than 300,000 (LCC, n.d.). The BCI of Leicester is 5.3 points (see Figure 1), which is slightly below average compared to other assessed West-European cities. The Blueprint indicates that the city is relatively vulnerable to flooding as one fifth of the city could potentially be flooded by the river Soar. Leicester has large opportunities to improve their urban water management, and thereby also minimise their flood risk. In particular, by increasing the coverage of green/blue space, reducing the average age of sewers, and by introducing stormwater separation in its sewer system. In comparison to other cities, areas with water and vegetation that can store excessive rainfall are limited and much of the city is surfaced with impermeable concrete, stones and asphalt. Subsequently, Leicester is particularly vulnerable to surface water flooding as a result of periods of both intensive and prolonged rainfall. Moreover, the average age of the sewer system is relatively high. Augmentation of this sewer by separated network poses opportunities to make the city more flood resilient (Strzelecka et al. 2017).

At this moment the performances on the conditions “green space” and “stormwater separation” could be strengthened to further minimise flood risk and improve urban water management. Therefore, in the following section the actions of other cities with a high performance on the previously mentioned indicators are examined.

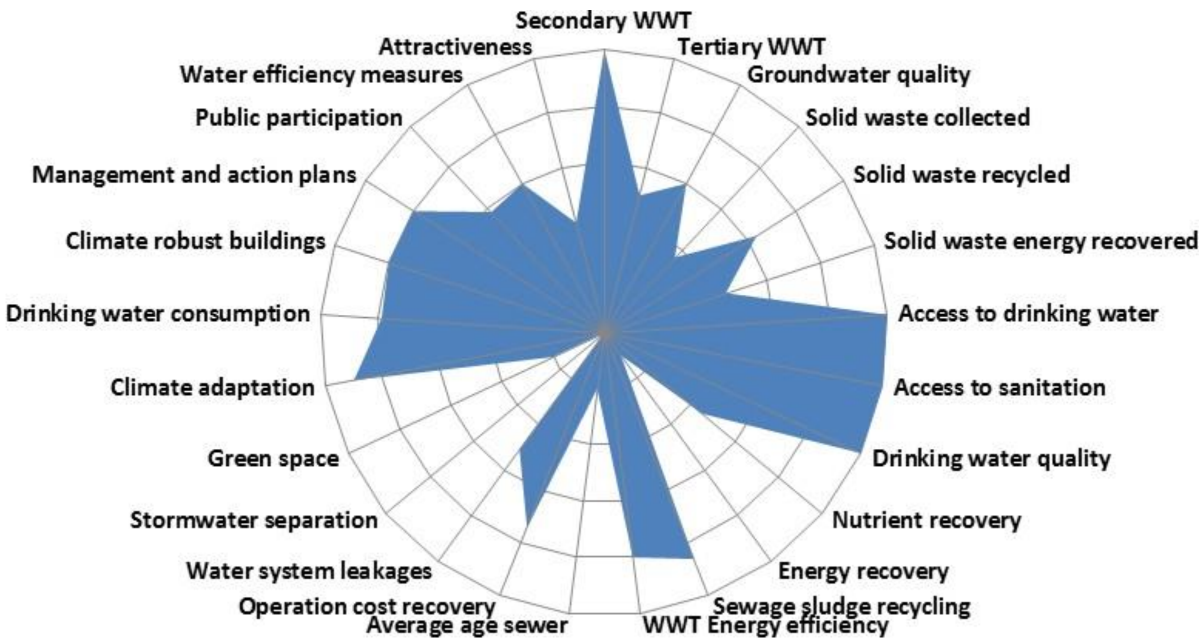

Figure 1 City Blueprint performance framework results for the city of Leicester, United Kingdom

3.2 Improvement options for Leicester

In this section, potential improvement options to tackle the key challenges (addressing stormwater separation and green space) of Leicester are discussed based on the performances of other cities in the world that score high on the indicators that need to be improved in Leicester. Leicester may learn from other cities to improve its IWRM performance.

3.2.1 Improving stormwater separation

The first challenge of Leicester is that stormwater is not separated from waste water streams. Leicester has approximately 330,000 residents (ONS, 2011a) at risk of potential flooding in the event of severe rainfall. Therefore, it is an important task for Leicester to include stormwater separation in sewer refurbishment efforts, which will also improve the age of sewers.

To improve stormwater management and protect the sewer system from damages, cities are starting to renovate the sewer system by separating rainwater from the sewer (Wavin, 2017). There are various advantages to stormwater separation. First, it is better for the environment in comparison to the conventional system. When there is heavy rainfall it regularly happens that the sewers have to process so much water in a short time that the sewer overflows. With this combined sewer overflow, dirty sewage flows into the surface water. By disconnecting as much as possible, the peaks volumes in the sanitary sewer will decrease. At the same time, the relatively clean rainwater no longer enters the sanitary sewer, and consequently, waste water treatment plants will perform better if the supplied waste water is less diluted by rainwater. Lastly, if the decoupled water is infiltrated into the soil, it is possible to supplement groundwater (HDSR, n.d.).

In the following sections we examine the cases of Melbourne (Australia) and Amsterdam (The Netherlands), since these cities score a high performance on "stormwater separation" in the City Blueprint.

Melbourne, Australia

In Melbourne, stormwater is generated when rainwater cannot soak into the ground due to impervious surfaces (e.g. pavements covered by asphalt). Subsequently, this water becomes runoff which can either run over land or through pipes and drains to waterways (Melbourne Water, 2013). The State Government of Victoria together with the local water supplier "Melbourne Water" have developed a "Stormwater Strategy". This strategy articulates "a shift in the way stormwater is managed to contribute to a more sustainable, prosperous, liveable and health community. It highlight the multiple community outcomes that may be achieved by implementing integrated stormwater management solutions and outlines the role Melbourne Water plays in managing stormwater" (Melbourne Water, 2013, p. 2). Melbourne's harvesting of rainwater and stormwater was boosted in order to replace drinking water. Stormwater has been identified as a fairly unexploited resource with potential to be used more efficiently to substitute existing drinking water demands (Melbourne Water, 2016).

Urban stormwater harvesting schemes vary in characteristics, but have some typical stages as illustrated in Figure 2. In the first stage, stormwater is collected from a source (usually a drain). In the second stage, stormwater is temporarily held in above or underground storages to balance supply and demand. In the third stage, stormwater is treated to reduce pathogen and pollution levels. In the last stage, the treated stormwater is distributed to the area of use, for instance to sporting facilities and industrial complexes (Melbourne Water, n.d.). The percentage of households with a rainwater tank increased substantially and urban stormwater was collected and treated to irrigate gardens, sport fields and golf courses (State Government of Victoria, 2015). To implement stormwater separation in Melbourne, approval must be obtained at Melbourne Water if the connection is to a drain, watercourse or open channel (Melbourne Water, 2016).

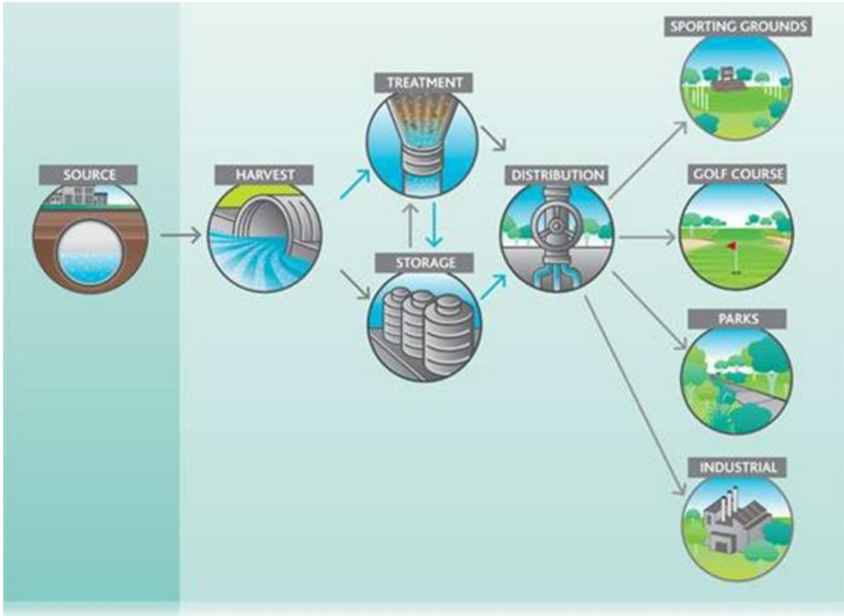

Figure 2 Stages of stormwater harvesting (Melbourne Water, n.d.)

Amsterdam, the Netherlands

Amsterdam is pioneering with a strategy that combines flood adaptation with infrastructural renovations and with measures to reduce heat stress, air pollution or water issues as a result of extreme precipitation (Koop et al., 2018; Dai et al., 2018). Due to the city's on-going population growth and resulting densification, infiltration is reduced, leading to higher runoff volumes as a consequence of increased impervious surfaces (City of Amsterdam, 2010). In order to address this challenge, Amsterdam is implementing a real-time sewer control system that optimizes the storage capacity of the sewer to ensure a constant flow to the waste water treatment plant (De Korte et al., 2009). Moreover, new gutters and storm water collection systems are constructed to temporarily store rainwater (Van der Hoek et al., 2014).

The local water supplier of Amsterdam, Waternet, has included a different sewer in new neighbourhoods than the sewers in the old neighbourhoods. In the old neighbourhoods there is a combined sewer system, where stormwater runoff is combined in a single pipe with waste water from homes, businesses and industry. During drier weather, the stormwater and waste water are carried to the sewage treatment plant together. But in heavy rains, high volumes of stormwater can exceed the capacity of a combined sewer system. The excess, untreated waste water overflows directly in natural waterways. In the new neighbourhoods, rainwater and waste water are collected separately (see Figure 3). The rainwater can be released directly into a river, channel or pond. Whereas waste water is treated first before it is released into surface water (Waternet, n.d.). About 75% of Amsterdam's sewers collects stormwater separately which strongly reduces water pollution through combined sewer overflows during storm events. On an online platform which is called "Amsterdam Rainproof", ideas, initiatives and information on how to make Amsterdam rainproof are shared, which includes the idea of stormwater separation.

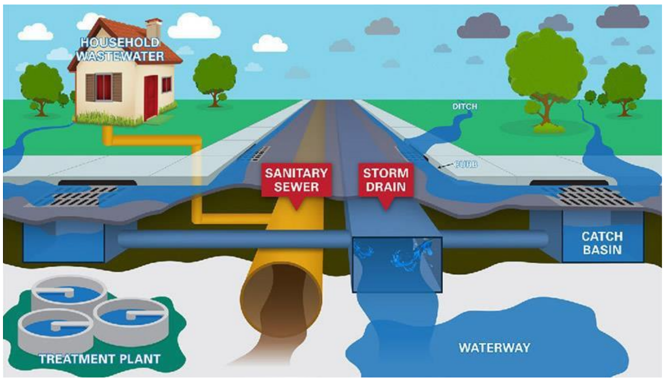

Figure 3 Separated sewer system (Storm, 2019)

3.2.2 Increasing blue-green space

Cities frequently face multifaceted and interconnected environmental, social and economic problems (e.g. climate change, waste management and food security). Traditionally, these issues have often been treated as isolated issues to be addressed using conventional "grey" solutions such as roads, buildings or dikes. However, as the discourse on sustainability has progressed, city planners and decision-makers have experimented with innovative solutions which strive to reduce negative environmental impacts (Barton, 2016). The strategic implementation of Urban Green Infrastructure (UGI), e.g. parks, green roofs as well as blue and green spaces can make a significant contribution to reduce stormwater runoff (Zimmermann et al., 2016; EEA 2012), facilitate temperature reductions in cities while delivering co-benefits such as pollution alleviation and biodiversity (Norton et al., 2014). A low share of green area makes a city more vulnerable to urban drainage floods and heat waves. There is evidence that increased mortality and morbidity from extreme heat events are exacerbated in urban populations by the Urban Heat Island (UHI) effect (Heaviside et al., 2016; Norton et al., 2014). To substantially reduce this effect, widespread implementation of blue-green infrastructure is required. UGI can be defined as "the network of planned and unplanned green and blue space, spanning both the public and private realms, and managed as an integrated system to provide a range of benefits. UGI can include remnant native vegetation, parks, ponds, private gardens, street trees and more engineered options such as green roofs and green walls" (Norton et al., 2014; EEA 2012). The European Commission has developed a green infrastructure strategy. This strategy aims to ensure the protection, restoration, creation and enhancement of blue-green infrastructure become an integral part of spatial planning and territorial development whenever it offers a better alternative, or is complementary to, standard green choices (EC, 2016).

Figure 4 Example of how a green roof can reduce stormwater volumes by up to 85% (City of Melbourne, n.d.)

In the following sections we examine the case of Malmö (Sweden), since this city scores a high performance on "green space" in the City Blueprint.

Malmö, Sweden

The urban area of Malmö consists of over 50% green space, including parks and green spaces in residential areas (Green Surge, 2015). Key climate challenges for the city concerned increased precipitation and heavy storms that enhance flood risks. The city of Malmö therefore widely implemented green roofs as a consequence of the introduction of "the green space factor". To achieve a certain amount of green space in the city and to minimise the sealed areas, the green space factor is used. This factor means that different types of surfaces are given different credits. No credit is given to sealed surfaces, low credits are given to unsealed but not green areas, whereas plant beds, climbing plants, green roofs and ponds are given high credit (Kruuse and Verchou, 2005). Developers can use this tool for calculating green space requirements for new developments (Lehner, 2017).

Green roofs are commonly used to describe roofs covered with vegetation. Establishment of vegetation on roofs can be divided into three management categories: extensive; semi-intensive and intensive. Firstly, the extensive roof can reproduce a natural landscape. Secondly, the semi-intensive roofs require a care that is more extensive than for extensive roofs, but which still can be less intensive than park-like environments. Thirdly, roof surfaces which are used for recreation. These roofs require high levels of maintenance, therefore roofs are intensive in their management. Green roofs have various benefits, especially in cities. These benefits include a richer flora and fauna, which in turn have a positive impact on biodiversity. Furthermore, green roofs help to reduce UHIs, can mitigate air pollution and reduce peak rainwater drainage and thereby could result in reducing floods (SGRI, n.d.). In Malmö there are many green roofs, especially in the Augustenborg residential neighbourhood, where almost all houses have at least one part with a green roof (Kruuse and Verchou, 2005). This neighbourhood has historically been susceptible to floods. A variety of nature-based solutions were used to construct an open drainage for the Augustenborg neighbourhood. The objective was to "handle the majority of rainwater via this open system, rather than the existing sewer system, using a network of green spaces, drainage channels, and holding ponds to reduce flooding by 70% and eliminate combined sewer overflow" (Barton, 2016, p. 24).

Green roofs thus have many benefits. The initial storage and (slow) release of stormwater provides a better climate, preserves biodiversity, has the potential to improve air quality, have an insulating effect, reduce noise and have a cooling effect on the urban environment (Cascone, 2019). To educate people about green roofs, guided tours and in-depth technical visits are organised to enhance the knowledge of people. These tours take place in the Augustenborg Botanical Garden (Figure 5). The rooftop contains more than 20 vegetated areas with different systems and "inspiration gardens for urban farming and biodiversity" (SGRI, n.d.). Additional benefits are also that it improves the aesthetic value of the neighbourhood, effectively increases house prices and simply increases the perception that it is a more attractive place to live.

Figure 5 Augustenborg Botanical Roof Garden (SGRI, n.d.).

3.3 Opportunities for Leicester to enhance sustainable urban water management

To improve sustainable urban water management, Leicester may focus on two aspects: stormwater separation and green space. In this previous section, we have examined the cases of Melbourne, Amsterdam and Malmö. In this section, we discuss what is needed to translate the best practices identified in these three cities to the case of Leicester.

Stormwater separation

Melbourne and Amsterdam showed examples of how stormwater can be harvested and how stormwater could be separated in the sewer system from waste water. Leicester is vulnerable to flooding as 20.7% of the city centre would be flooded if flood defences failed to protect against a one metre river level increase (EEA, 2012). Minimising flood risk is at the heart of Leicester City Council's (LCC) approach for the planning process. For example, LCC has developed a "Local Flood Risk Management Strategy" (LCC, 2015). This strategy document explains the Council's duties and responsibilities, together with those of other risk management authorities such as the Environment Agency, Internal Drainage Board and the local water company "Severn Trent Water". Much of the sewer network in Leicester dates back to the Victorian times and includes a combined sewer system (LCC, 2012) which require continuous relatively costly refurbishments. For new developments a separate system for sanitary and stormwater seems to be a good investment. As such, Severn Trent Water defined in their water management strategies to reduce its share of combined sewer overflows and sewer flooding by more frequent cleansing and maintenance on the short-term (STW, 2015), where combined sewer replacement by a separated system is the ambition for the long term (STW, 2007).

Green space

The green/blue coverage in Leicester is 22.5% which is relatively low in comparison to the best practice of Malmö (with 50% green/blue coverage). As such, Leicester is more vulnerable to stormwater runoff and the UHIs. To improve this, the city could learn from best practices such as Malmö. The Green Space Factor could be introduced in Leicester as a tool for calculating green space requirements for new developments, as it includes a checklist of 30 green and blue infrastructure options for developers. Other cities are also considering using this method including The Hague in the Netherlands (Lehner, 2017).

The example of green walls and green roofs would also be suitable for new developments in Leicester as it could then be considered in the planning process. The city of Leicester is already actively increasing green and blue area in the city in order to combat flooding, droughts and heat stress. The city council has developed a “Green Infrastructure Strategy (2015-2025)”, which sets out a strategic vision for the green sites in Leicester and the ways in which they can be created, managed and maintained (LCC, 2015). In the Green Infrastructure Strategy (p. 13) it is stated that “the city centre and inner areas are key targets for future investment, but have low levels of accessible green infrastructure and some have low functionality”. In this strategy, also green roofs and walls are mentioned as a potential way to increase green infrastructure in the city. At present, Leicester has a limited number of green roofs, but this is expected to increase in the future. However, the University of Leicester’s Centre for Medicine already has a green wall and roof which are designed in such a way to attract insects and birds which will help to promote biodiversity (University of Leicester, 2015). Besides green roofs and walls, multiple other green infrastructure examples are discussed in the Green Infrastructure Strategy including: trees, sustainable urban drainage systems, river corridors, and private gardens. Leicester is already showing some success cases, including the public park “Abbey Park”, which has regularly won the Green Flag award (a national award to recognise and reward the best green spaces in the UK) (LCC, n.d.). Moreover, a series of rain gardens were introduced on a closed highway area near De Montfort University (Susdrain, n.d.).

4 Improvement options for sustainable urban water management in Milton Keynes

This chapter provides an overview of the challenges that Milton Keynes faces regarding sustainable urban water management. Based on the key challenges provided by the City Blueprint performance framework, improvement options for Milton Keynes are provided based on best practices. Furthermore, it is examined what is needed to translate these improvement options to the case of Milton Keynes.

4.1 Overview of key challenges

Milton Keynes is a relatively new city with approximately 249,000 inhabitants which is expected to increase considerably in the future (ONS, 2011b). The Blue City Index (BCI) of Milton Keynes is 6.5 points which is amongst the higher scoring cities in West-Europe (Figure 6). Milton Keynes has a high performance on indicators such as green space, climate adaptation and drinking water consumption which is beneficial for the city since it is located in one of the driest regions in the UK. Figure 6 also shows that there are two main challenges (as they score a low performance of 0 points), namely the energy recovery from waste water and nutrient recovery from waste water. Although Milton Keynes is a high performing city, these two indicators are lacking behind. These indicators reflect the reuse the resources of waste water as a fraction of the waste water that is treated with energy and nutrient recovering techniques. If techniques for the recovery of nutrients and energy would be applied, the BCI would increase substantially to amount to 8.0 points. When improvements are made to these indicators, Milton Keynes has the potential to be amongst the highest scoring cities in the 75 City Blueprint that have been assessed so far.

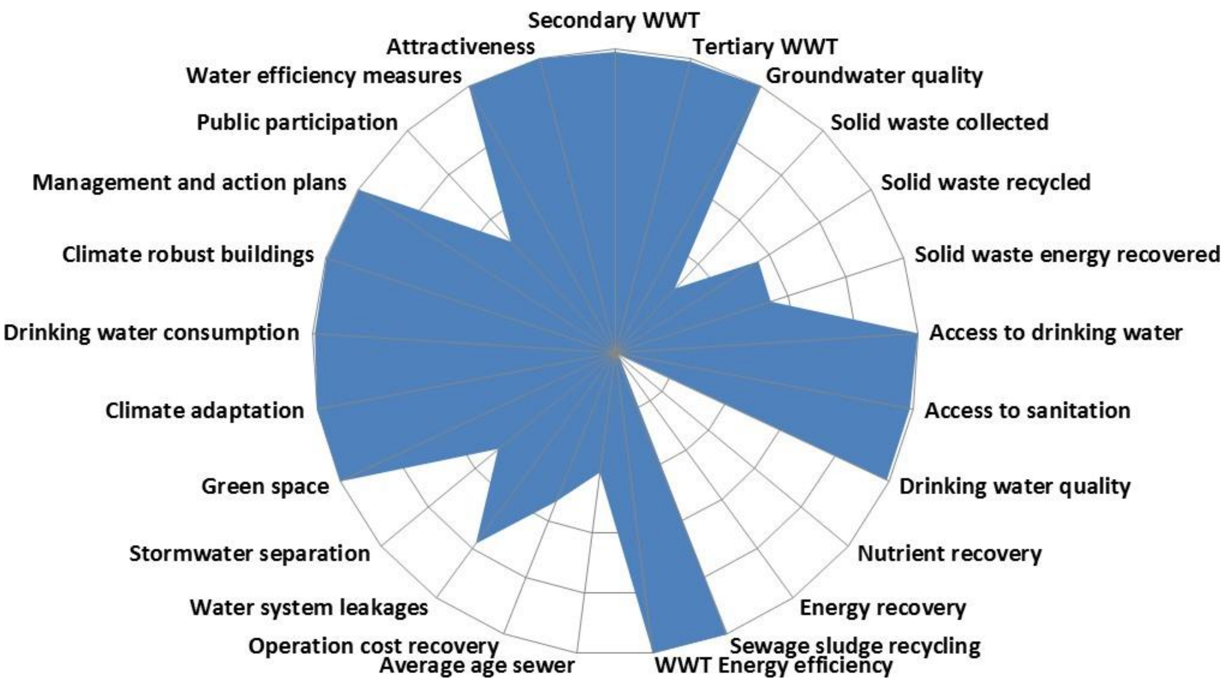

Figure 6 City Blueprint performance framework results for the city of Milton Keynes, United Kingdom

4.2 Improvement options for Milton Keynes

In this section, potential improvement options to tackle the key challenges (nutrient recovery and energy recovery) of Milton Keynes are discussed based on the performances of other cities in the world that score high on the indicators that need to be improved in Milton Keynes. Milton Keynes may learn from other cities to improve its IWRM performance.

4.2.1 Improving nutrient recovery

The first challenge of Milton Keynes is the lack of nutrient recovery from waste water. Nutrients are essential for life and their future availability must be guaranteed. Tracking the flows of nutrients and routing them back into the biological cycle can prevent them from going to waste. Waste water has for a long time been considered as a human health concern and environmental hazard, but the paradigm is shifting from considering waste water solely as waste to be treated towards a proactive interest in recovering materials and energy from waste water. Subsequently, treated waste water can be reused for various purposes which in turn can provide ecological benefits, reduce the demand of potable water and augment water supplies (van der Hoek et al., 2016).

Nutrient recovery from waste water is also important to decrease surface water pollution. This holds especially for phosphorous and potassium which are finite resources and will become increasingly expensive and more difficult to mine (Cordell and White, 2011; EC, 2014). There are valuable nutrients which often end up in domestic waste water. Zeeman (n.d.) calculated that recovering phosphates from black and grey water could satisfy “a quarter of the present worldwide artificial phosphorus fertiliser use”.

About half of the 75 assessed cities do not apply any form of nutrient recovery. The reuse of nutrients can either be done through using the sewage sludge on agricultural land or by producing struvite (a phosphate mineral) from waste water. At this moment, many cities including Milton Keynes do not apply nutrient recovering techniques in their waste water treatment. Beyond, phosphate increasing research and innovation is focussed on the recovery of other resources from waste water for use in the construction and paper industry, or for medical appliances (Van Leeuwen et al., 2018). These initiatives form an interesting and important part of sustainable water management.

In the following section we examine the case of Amsterdam (the Netherlands) as the city scores a high performance on “nutrient recovery” in the City Blueprint.

Amsterdam, the Netherlands

Waste water contains valuable substances, including phosphate. Since 2013, phosphate has been recovered in the City of Amsterdam from domestic waste water. Phosphate is becoming a scarce resource worldwide. Studies have indicated that the stocks of phosphorus will be depleted in 50 to 100 years (De Jong, 2017). It is an essential, finite and irreplaceable nutrient in the agricultural sector. Therefore, reusing and recovering phosphate is increasingly becoming attractive and important. In 2006, the regional water authority and the municipality of Amsterdam established a new centralised waste water treatment plant operated by the local water supplier Waternet. It is one of the largest sewage water purification systems in the Netherlands.

The struvite installation in Amsterdam produces 2,500 kilos of struvite per day. To illustrate this, 10,000 football fields can be fertilised with this number every year. To implement the technique that recovers struvite from waste water, the installation named “Fosvaatje” was developed. The installation was connected to the existing treatment plant in 2013 (De Jong, 2017; Nutrient Platform, n.d.). Besides recovering phosphate from waste water, Waternet is investigating whether proteins can be recovered from sewage water, which can for example be used for animal feed (Waternet, 2016). In the Netherlands, a “Green Deal” has been established called the "Energy and Raw Material Factory". Here, business, universities, regional water authorities and the government in order to boost innovation and explore new markets for the recovered materials (Van Leeuwen et al., 2018).

4.2.2 Improving energy recovery

The second challenge of Milton Keynes is the lack of energy recovery. Waste water can be used as a resource, since it contains many resources like nutrients but also energy. Energy recovery is a waste treatment process that generates energy in the form of biogas and heat. Energy recovery techniques at waste water treatment plants can be considered as a renewable resource like solar power or wind energy since it does not produce net CO_2-equivalent emission in its energy generation. Biogas is particularly interesting as a renewable resource because it is, unlike wind power or solar power, relatively regular supply. Hence, it can form an essential part of the renewable energy mixture of the future.

Waste water can be used as an energy carrier, but also contains energy itself including either chemical energy or thermal energy. With respect to waste water, chemical energy concerns the organic compounds which are present in the waste water whereas thermal energy often refers to the heated waste water that leaves households. Chemical energy recovery from waste water is based on anaerobic sludge digestion and anaerobic treatment of waste water. Thermal energy can also be recovered from waste water, and there are several possibilities for recovering thermal energy. For example, at household level, a heat exchanger is an option (Maktabifard et al., 2018).

In the following section we examine the case of Amsterdam (the Netherlands) as the city scores a high performance on "energy recovery" in the City Blueprint.

Amsterdam, the Netherlands

To achieve the ambitions of the City of Amsterdam to be the core city of an internally competitive and sustainable European Metropolis, the circular city concept is adopted. This concept is specified in various policy documents, including the "Sustainability Agenda Amsterdam" (City of Amsterdam, 2015). Recovery of resources and materials is one of the targets mentioned in this document. Waternet, the public water utility of Amsterdam, aims to recover resources from Amsterdam's waste water (van der Hoek et al., 2016) as it will contribute to their ambition to operate climate neutrally in 2020.

In sum, Waternet produces 13 million m^3 biogas per year at 12 waste water treatment plants. Biogas is mainly upgraded to "green gas". For example, green gas produced at a relatively small plant is for 20% used to heat the buildings and sludge digestion process at the treatment plant, and 80% is distributed to households or used as fuel for company cars (van der Hoek et al., 2016).

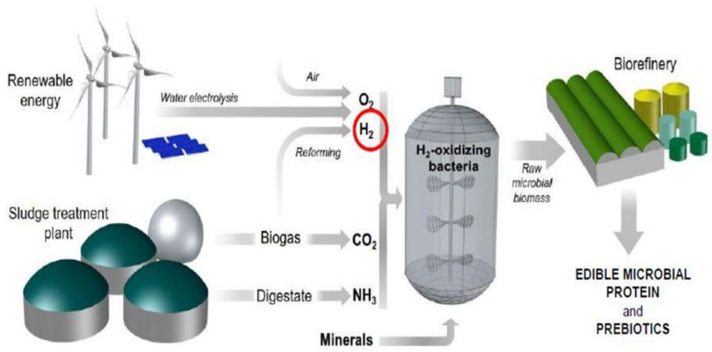

Figure 7 Illustration of processes how nutrients and energy can be recovered from sludge treatment process (Waternet, 2019)

In addition to chemical energy, waste water contains thermal energy that can be used for heating and cooling of buildings. Thermal energy is increasingly recognised as a sustainable alternative to natural gas heating. In 2018, Waternet explored the use of thermal energy. The water utility renovated a district "Buiksloterham" according to the rules of the circular economy concept. One of the developments within this project is that heat is recovered from greywater of households. By linking a heat exchanger to a heat-cold storage at each household or apartment block, the heat is extracted from greywater and transported back to the households for reuse. Furthermore, a bio-refinery is developed within this district which is a small-scale treatment unit in which materials and energy can be recovered from black waste water (Waternet, 2019).

4.3 Opportunities for Milton Keynes to enhance sustainable urban water management

To improve sustainable urban water management in Milton Keynes on two aspects (energy recovery and nutrient recovery), we examined the best practices of Amsterdam. In this section, we discuss what is needed for these best practices to be translated to Milton Keynes.

Nutrient recovery

About half of the 75 cities assessed by the City Blueprint, do not apply any form of nutrient recovery, either because they are not aware or there is no market to apply struvite or other recovered resources. To improve urban water management in Milton Keynes and thereby strengthen its performance on the indicators of the City Blueprint, the city could recover nutrients from waste water. Since Milton Keynes is situated in one of the driest regions of the United Kingdom, the reuse of waste water would be very beneficial for augmenting water supplies. Furthermore, the best practice of Amsterdam illustrated that valuable resources can be recovered from waste water including phosphate. Milton Keynes may learn from other cities in the City Blueprint on how to recover nutrients such as phosphate, but also from pilot projects such as the one on protein recovery in Amsterdam. However, it is good to note that the privatized company Anglian Water already includes nutrient recovery during wastewater treatment processes. Anglian Water supplies water and recycling services to, among others, Milton Keynes (Anglian Water, n.d.). The water company has created a "Renewable Energy Strategy" which aims to reduce carbon for instance by making better use of the by-products from treatment processes. (Anglian Water, 2019). In the "Anglian Water Bioresources Strategy 2020-2045" it is stated that the company returns "valuable nutrients and organic matter to farmland" as this "improves the soil and plant health and so has significant natural capital benefits" (Anglian Water, 2018, p.2-3). This indicates that the water company is already recovering nutrients, but this is not at a city level since the agricultural land is not part of Milton Keynes City.

Energy recovery

The second indicator that can be improved in Milton Keynes is the recovery of energy from waste water. As mentioned in the previous section, the regional water utility Anglian Water already includes nutrient recovery in its treatment processes. This is also the case for energy recovery. Again, this is on the regional level which therefore not specifically the case for Milton Keynes. The water company has ten sludge treatment centres and combined heat and power engines throughout the East of England which create energy from the biogas released as a by-product of the water recycling process: "through our Bio-Resources Strategy we are maximising the generation of renewable energy from these by-products and we are also working with the agricultural sector to recycle these nutrients to land" (Anglian Water, n.d.). Most of the renewable energy that is generated is used on site operation and excess energy is exported to local electricity works. Similar to the local water utility of Amsterdam, Anglian Water also has the long-term ambition to be carbon neutral by 2050 (Anglian Water, 2018).

5 Improvement options for sustainable urban water management in Jerusalem

This chapter provides an overview of the challenges that Jerusalem faces regarding sustainable urban water management. Located in a semi-arid climate, the issue of water conservation is of major importance for the city. Based on the key challenges identified by the City Blueprint assessment frameworks, improvement options for Jerusalem to enhance water conservation will be provided. Moreover, potential consequences of these measures are discussed.

5.1 Overview of key challenges

The city of Jerusalem, Israel, is one of the oldest cities in the world and has approximately 882,700 residents (JIPR, 2018). The Blue City Index for the city of Jerusalem is 6.0 points (Figure 8). The city scores a high performance on indicators related to climate change adaptation, water infrastructure and waste water treatment, whereas it scores low on green space and indicators related to solid waste. Jerusalem is situated in a dry climate and one of its key water-related challenges is water scarcity. It is therefore important to improve blue-green infrastructure in the city since this will reduce the UHIs in the city. The best practice of Malmö, as described in Section 3.3, can also form an example for Jerusalem. In addition to the best practices, the DSP has led to strengthening the efforts of increasing green space in Jerusalem through community gardens (as discussed in detail in Deliverable 4.8). Another important point for improvement is the city's treatment of solid waste. The per capita waste production is relatively high, whereas the recycling of waste is low and there is no energy recovered from the collected solid waste. These issues related to solid waste form therefore a key point for improvement and is the focus of the following sections.

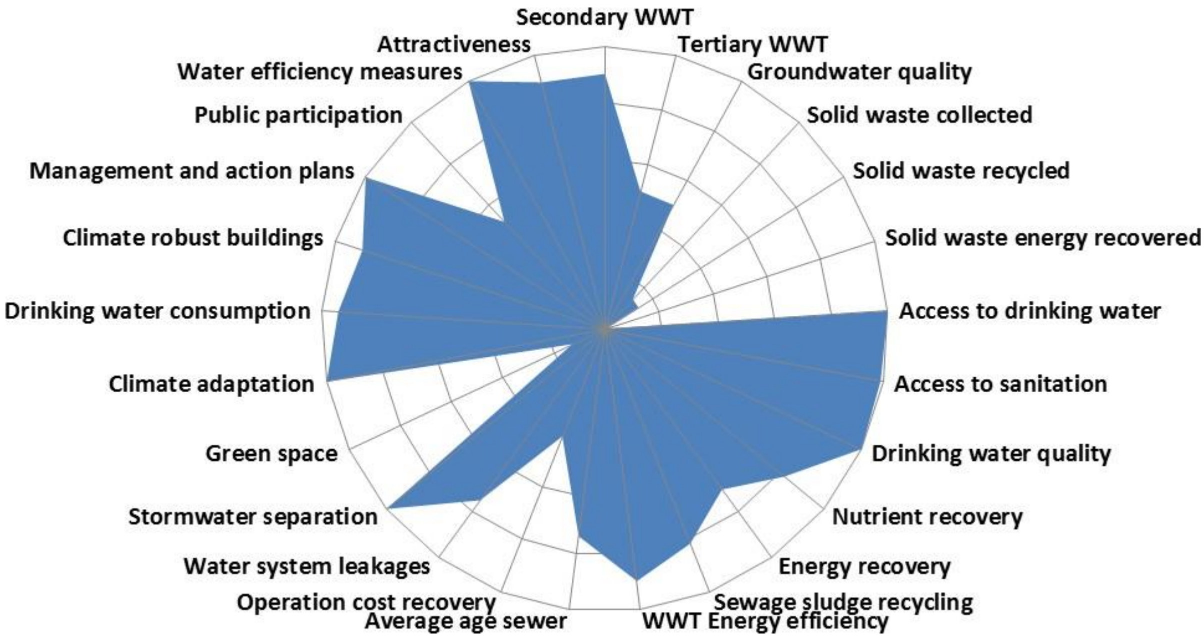

Figure 8 City Blueprint performance framework results for the city of Jerusalem, Israel

5.2 Improvement options for Jerusalem

In this section, potential improvement options to tackle the key challenges (solid waste recycled and solid waste energy recovered) of Jerusalem are discussed based on the performances of other cities in the world that score high on the indicators (best practices) that need to be improved in Jerusalem.

5.2.1 Improve solid waste recycled

The first challenge of Jerusalem relates to the indicator “solid waste recycled”. Cities generate vast amounts of solid waste which releases dangerous substances (e.g. plastics that pollute surface water, rivers and ocean ecosystems). Moreover, the recovery and reuse of energy and materials from solid waste is important in reducing resource dependency and alleviating the city’s environmental impact on ecosystems. In general, insufficient waste management causes air, water and soil contamination (Rahmasary et al., 2019; Koop, 2019). Recycling is the process of converting waste materials into new materials and objects. For example, organic waste is rich in the vital nutrient phosphorus; waste electronics contain increasingly scarce metals such as aluminium and copper. Recycling is an alternative to the conventional waste disposal that can save materials and help lower GreenHouse Gas (GHG) emissions. GHG emissions from open dump land-filling are about 1000 kg CO_2-equivalent tonne^{-1} of solid waste, whereas this can be significantly reduced to 300 kg CO_2-equivalent tonne-1 for conventional landfilling. It can be a carbon sink when most material is recycled and the energy is recovered (Manfredi et al., 2009; Koop, 2019). The global GHG emissions of solid waste disposal sites are approximately 5-20% of the global anthropogenic methane emission or 1%-4% of the total anthropogenic GHG emissions (IPCC, 2006; Koop & Van Leeuwen, 2017). In the EU Waste Directive (Directive 2008/98/EC) one of the objectives set out is that 50% of the household waste should be recycled in 2020, and a roadmap for a resource efficient Europe in 2050 has been developed (EC, 2008; EC, 2011).

In the following section, we examine the case of Copenhagen (Denmark) and Oslo (Norway) as these cities scores a high performance on “solid waste recycled” in the City Blueprint.

Copenhagen, Denmark

The city of Copenhagen is the capital of Denmark with approximately 600,000 residents (Chang & Pires, 2015). One of the main objectives of the city is to become carbon neutral in 2025, and similar to the best practice of Amsterdam, circular economy and sustainability are important focus areas of Copenhagen. The City Council has introduced the “Resource and Waste Management Plan” for the period of 2013-2018. The plan aims to increase waste being recycled as well as the prevention of waste (Urban Waste, n.d.). The waste hierarchy (Figure 9) guides the efforts described in the management plan. The purpose is to lift waste management in Copenhagen as much up the hierarchy as possible. This has been derived from the EU Waste Directive, which describes that the best idea is to prevent waste from being generated and to landfill as little waste as possible.

Figure 9 The waste hierarchy sets the priorities in the management of waste (City of Copenhagen, 2014)

Copenhagen sends less than 2% of waste to landfills, and approximately 60% of the waste is recycled and maximum use is made of the residual waste to generate heat for the city's district heating network (see Section 6.2.2). The city now has six local recycling hubs, and in the future there will be three more (City of Copenhagen, 2014). At the moment all households separate recyclable waste and more products are introduced together with the development of new sorting technologies. The products collected from the households at the moment are: paper, cardboard, metal, rigid plastic, hazardous waste, glass, electronic waste and residual waste. Bulky waste and garden waste can be collected from the households by agreement with the municipality or be delivered at the recycling stations (Urban Waste, n.d.). There is a great demand for Danish waste solutions from an international perspective, and the Danish waste sector has grown 66% during a five-year period (Copenhagen Capacity, 2012).

Oslo, Norway

Oslo is the capital of Norway, and has approximately 670,000 residents (Statistics Norway, 2018). The city of Oslo has set an overall target to reduce its CO_2 emissions by 50% by 2030 and to become carbon neutral by 2050. One of the measures the city has taken to achieve this target is an integrated waste management system. In 2006, Oslo established the "Waste Management Strategy towards 2025". This strategy sets ambitious goals linked to a circular economy (EC, n.d.). As seen previously in Copenhagen, the city of Oslo also promotes the waste management hierarchy, where incineration and landfills are seen as the least desirable form of waste management. The strategy mainly focuses on waste reduction, reuse and recycling (C40 Cities, 2016).

The European Commission has awarded Oslo the European Green Capital title for 2019 (City of Oslo, 2019). This is not only a recognition, but also an opportunity for Oslo and its population. In this way, the city needs to be a leading example to other cities, also in terms of waste management. As Oslo includes all elements of waste production, collection and treatment process, household waste is separated at source and collected according to the waste type aiming to attain clean waste streams for recycling. A green bag is used for food waste, a blue bag is used for plastic waste, and a white bin is used for paper and cardboard; whereas there are also separate containers for other waste including glass, fabric, electronic and hazardous waste (City of Oslo, n.d.; Ruhm, 2016).

In 2018, the average annual waste production per capita in Oslo was 321 kg, while the national average was 430 kg. It may seem like increased facilitation of source separation and public awareness campaigns have had a positive effect in Oslo (City of Oslo, n.d.). In order to support the extension of source separation, the

City of Oslo introduced campaigns to encourage better waste management among citizens. The campaigns include: communication and advertising campaigns in the media and in public spaces; involving celebrities to promote source separation, and door-to-door campaigns. This communication strategy has four phases: 1) to raise awareness; 2) to increase knowledge of results and benefits of recycling ; 3) increasing knowledge of how the recycling systems work and the effects of recycling; and 4) change the behaviour of citizens. When citizens do not follow the regulations set out in the Waste Management Strategy, the city has the right to sanction them. At this moment, no sanctions have been imposed on citizens. The City of Oslo is however considering sanctioning housing cooperatives as waste separation rates are low, even after the municipality has paid these cooperatives visits and information campaigns have been implemented (EC, n.d.). One of the main challenges remaining for Oslo is thus changing citizens' behaviour, specifically correctly separating their household waste (EU, n.d.). Waste handling is fully financed by citizens, the "pay as you throw" principle is applied as household charges depend on the bin size, beginning at 443 Euros per year for 140 litres bins with weekly collection. The collection and use of delivery facilities for paper is free.

An optic waste sorting plant was opened in 2010 in Oslo, which is also the world's biggest optic sorting plant for household waste. The various coloured bags are separated by the plant by means of optic recognition. Subsequently, this waste is recycled (Figure 10). Garden waste is composted and sold to citizens as soil so they can use it in their gardens. No biodegradable waste is sent to landfills as this has been prohibited in Norway since 2009. Oslo also owns a biogas plant, which has a capacity for 50,000 tonnes of biological substances. The plant transforms food waste into biogas and bio-fertilisers. Biogas is used as fuel by buses and garbage collection trucks in the city. The bio-fertilisers are used by farmers to produce food (Luccarelli & Røe, 2013; EU, n.d.).

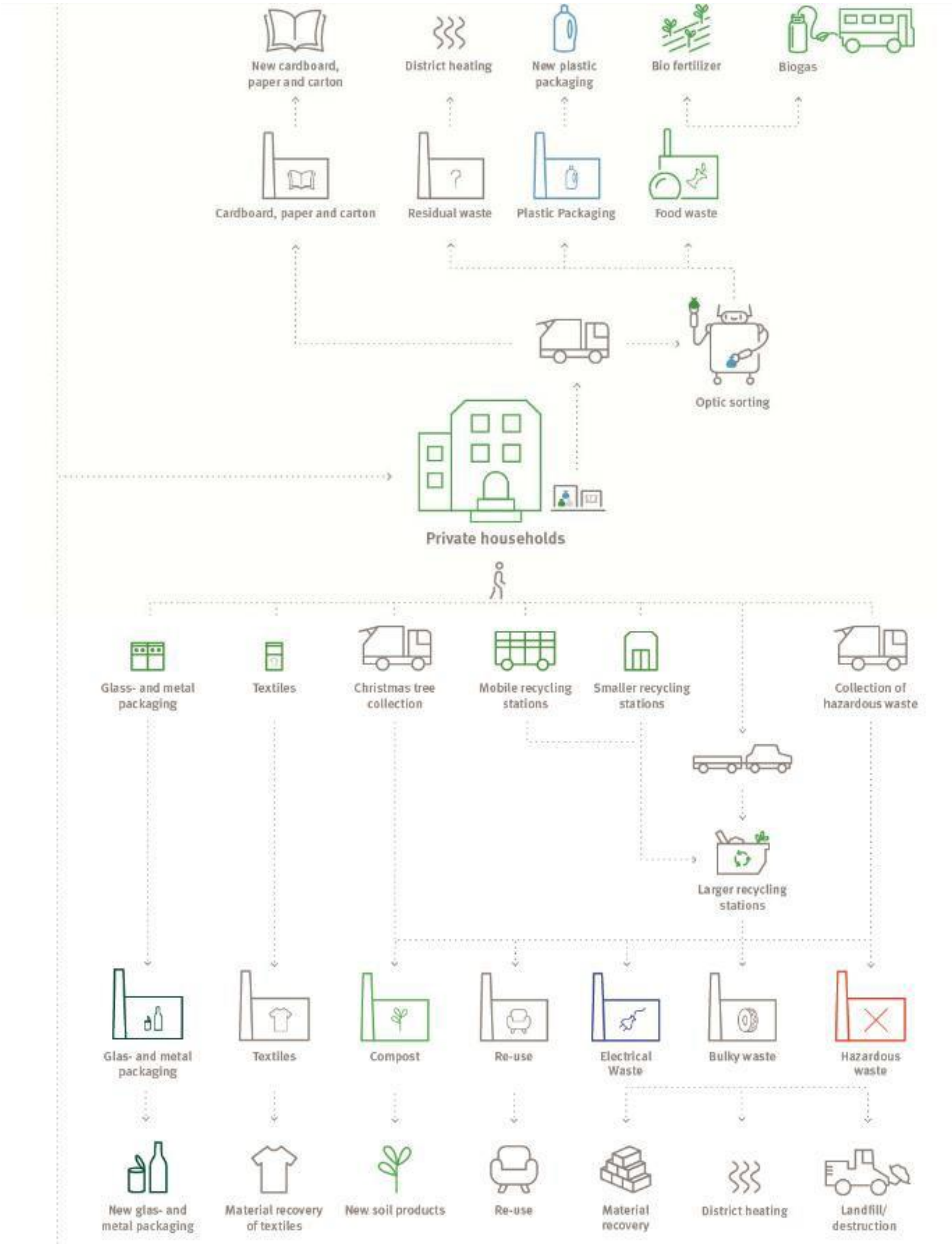

Figure 10 The waste collection, recycling and recovery system applied in Oslo, Norway (EU, n.d.)

5.2.2 Enhance solid waste energy recovered

Only when the reuse or recycling of waste products is not an option, energy recovery becomes a sustainable option (Figure 9). The waste system's energy outputs are multiple, and some outputs have more than one application. The outputs include electricity, heat and fuels such as biogas (Fruergaard et al., 2009). Electricity is in general generated by thermal treatment or utilisation of gas from anaerobic digestion. Thermal treatment such as waste incineration is a generic term for all waste management processes involving high temperatures (Fruergaard et al., 2009). On the other hand, anaerobic digestion is "a biochemical treatment process that allows stabilizing a myriad of organic wastes […] while simultaneously producing renewable energy, recovering fibres and nutrients for soil amendment, and offsetting GHG emission" (Labatut & Pronto, 2018). Biogas produced from anaerobic digestion may be in turn used to generate heat and electricity. However, it can also be used as fuel for vehicles, replacing fossil fuels (Fruergaard et al., 2009). Energy in the form from heat can also be recovered from waste, which can in turn be distributed through district heating networks (Muznik, n.d.).

The EU waste hierarchy (Figure 9) puts prevention, reuse and recycling first, followed by recovery and disposal. Efficient Waste-to-Energy plants belong to the recovery category: they turn non-reusable, non-recyclable waste into energy, thereby reducing the need for landfilling, which is the least desirable option due to high environmental impacts (e.g. potential groundwater pollution and methane emissions). There are differing opinions about energy recovery from solid waste as some say that valuable materials are lost (Muznik, n.d.), while recycling and composting can save up to five times the amount of energy produced by burning waste. It can also have negative impacts on human health and the environment due to the release of pollutants that contaminate air, soil and water. The guidance of the European Commission (2017) emphasises that generating energy from waste that cannot be recycled or reused can still contribute to a circular economy and energy diversification. Improving the efficiency of this process will help to increase energy production and reduce GHG emissions from the waste sector. Furthermore, the IPCC (2007) states that "compared to landfilling, waste incineration and other thermal processes avoid most GHG generation, resulting only in minor emissions of CO_2 from fossil cabon sources, including plastics and synthetic textiles".

In the following section we examine the case of Stockholm (Sweden) as this city scores a high performance on the indicator "solid waste energy recovered" of the City Blueprint.

Stockholm, Sweden

Most of the household waste in Stockholm is incinerated for energy recovery, whereas waste in landfills is almost non-existent. Sweden recovers more energy from each tonne of waste than any other country (SCS, n.d.). The City of Stockholm has set out various objectives related to waste management in their "Waste Management Plan" for 2017-2020. One of the objectives mentioned in this plan is that at least 70% of food waste is to be collected for biogas production and nutrient recovery (Stockholm Vatten och Avfall, n.d.).

At this moment, the waste of Stockholm is recycled as district heating, electricity, biogas, bio-fertiliser and materials. Different treatment methods are used depending on the nature of the waste. In 2015, a new plant was taken into operation for the digestion of food waste in Stockholm. The plant can convert 50,000 tonnes of food waste to biogas every year (Scandinavian Biogas, n.d.). This is approximately one third of all food waste created in Stockholm. The food waste is collected and then converted to renewable biogas and bio-fertiliser. The plant has a capacity of 80 GWh biogas which is up to 8.8 million litres of petrol. Moreover, approximately 14,000 tonnes of bio-fertiliser can be generated every year (ibid). Figure 11 illustrates how food waste is processed into biogas and bio-fertilisers in Stockholm. The first step shows that biogas is produced by collected food waste from households, schools and restaurants. In the second step the unwanted materials such as plastic and metal is sorted out. In the third and fourth step, the food waste is processed into food waste slurry, it can then be stored before it is pumped on to a process building where it is heated. The aim is to kill any bacteria. In the fifth and sixth step, the food waste is pumped into the plant's digesters where flood slurry is processed into raw gas. In the seventh step, the raw gas needs to be purified as it can then be used as fuel. After this purification, a high-quality fuel remains which is often referred to as biogas. In the eighth step the biogas is stored in a series of connected gas cylinders placed in containers which can then be transported to a biogas plant. In the next step, vehicles can use the fuel that is processed by the food waste plant. The remainder of the process is the extraction of additional raw gas from residue. Afterwards, the residue remains a high quality and environmentally-friendly bio-fertiliser that can be used to replace chemical fertilisers. The bio-fertiliser contains important substances such as nitrogen, phosphorus, potassium and magnesium that are returned to the soil through agriculture. In the last step, the liquid from the digestate is taken care of and concentrated by evaporation (Scandinavian Biogas, n.d.).

Swedish energy recovery plants also treat waste from other European countries, which contributes to the fuel supply in Sweden and helps provide solutions to some of the waste management issues in the countries the waste comes from (Vattenfall, n.d.).

Figure 11 Illustration of how food waste is processed into biogas and biofertilisers in Stockholm (Scandinavian Biogas, n.d.)

5.3 Opportunities for Jerusalem to enhance sustainable urban water management

To improve sustainable urban water management in Jerusalem on two aspects (solid waste recycled and solid waste energy recovered), we examined the best practices of Copenhagen, Oslo and Stockholm. In this section, we discuss what is needed to translate these best practices to Jerusalem.

Solid waste recycled

The City Blueprint assessments of 75 cities show that only the best performing cities applied solid waste recycling and energy recovery for most of their solid waste, while solid waste production was still high (Koop & Van Leeuwen, 2015a). To improve solid waste recycling in Jerusalem, we examined the cases of

Copenhagen and Oslo. When comparing these two cases it is notable that both cities have an ingrained strategy or plan on urban waste management which set clear targets on recycling. Furthermore, both Copenhagen and Oslo follow the waste hierarchy as described in the EU Waste Directive. This is something the city of Jerusalem and many other cities that perform low can learn from: to set long-term objectives and make a detailed strategy how to achieve these objectives following for instance the circular economy approach or the waste hierarchy.

Recycling is at this moment not mandatory in Jerusalem, but it has been increasing over the past few years. There are machines that separate metal, plastic, paper, cardboard and organic material. The recyclable products are then sold to other countries that will reuse the material, whereas the organic matter is composted. The rest is sent to landfill, although there are plans for incineration in the future (Jerusalem Post, 2017). Another important lesson from the best practices is that the behaviour of citizens should be changed in order to successfully recycle waste. This can be done through communication campaigns which focus on raising awareness and increasing knowledge. In the comparison between the best practices and Jerusalem it is important to note that the case areas are slightly different. For instance, Jerusalem has a population of approximately 882,700 residents (JIPR, 2018) whereas Copenhagen has a population of nearly 670,000 (Statistics Norway, 2018). Furthermore, Copenhagen has a long history in waste management. Therefore, it could take the city of Jerusalem more effort to recycle waste as it requires significant infrastructure needs, and the behaviour of a significant group of people needs to be changed, as well as the regulatory system on waste.

Solid waste energy recovery

From the 75 cities assessed by the City Blueprint, 30 cities used less than 50% of their potential to apply energy recovery from solid waste (Koop & Van Leeuwen, 2015a). For instance, cities in Germany burn 21% of their total solid waste without energy recovery (OECD, 2013). On average 47% of the solid waste is disposed in landfills where it produces large amounts of greenhouse gases and may lead to water pollution. As mentioned previously, only the best performing cities applied energy recovery techniques which shows that there is a lot of potential for improvements in many cities, including Jerusalem. Although Jerusalem can learn from a best practice such as Stockholm, it should be noted that energy recovery is not the ultimate goal of waste management. The focus should be on prevention, recycling and reuse first before energy recovery. If materials cannot be recycled, energy recovery can be a good alternative to ensure that valuable resources are not lost. The Waste Management Plan is an important guideline for the city of Stockholm, which sets out objectives related to energy recovery. Jerusalem may learn from this that it is first important to make clear guidelines on waste management.

6 Improvement options for sustainable urban water management in Sabadell

This chapter provides an overview of the challenges that Sabadell faces regarding sustainable urban water management. Based on the key challenges provided by the City Blueprint performance framework, improvement options for Sabadell will be provided based on best practices. Furthermore, it is examined what is needed to translate these improvement options to Sabadell.

6.1 Overview of key challenges

Sabadell is the fifth largest city in Catalonia, Spain, and is home to over 211,000 residents (GENCAT, 2018). The Blue City Index for the city of Sabadell is 3.7 points which is below average compared to other West-European Cities assessed to date (see Figure 12). The city has a low drinking water consumption rate of 97 litres/person/day (covering both industrial and domestic consumption), which is low compared to for instance a city as Amsterdam that has an average consumption of 133.4 litres/person/day (Waternet, n.d.). This is beneficial as water scarcity is one of the main concerns for Sabadell. As mentioned previously, key challenges are related to the indicators that score a low performance on the City Blueprint (0-2 points). For Sabadell there are multiple key challenges, including: stormwater separation, average age sewer, energy recovery, nutrient recovery and public participation. Although energy and nutrient recovery from waste water are not applied in Sabadell, these two challenges have previously been discussed for Milton Keynes whereas stormwater separation is discussed for Leicester. Therefore, we focus on best practices on the following two challenges: public participation and average age of the sewer system. Concerning the sewer system, there is room to improve non-registered water rates which amount up to 19.4% (covering leakage rates and measurement deviations; Aigues de Sabadell, 2016).

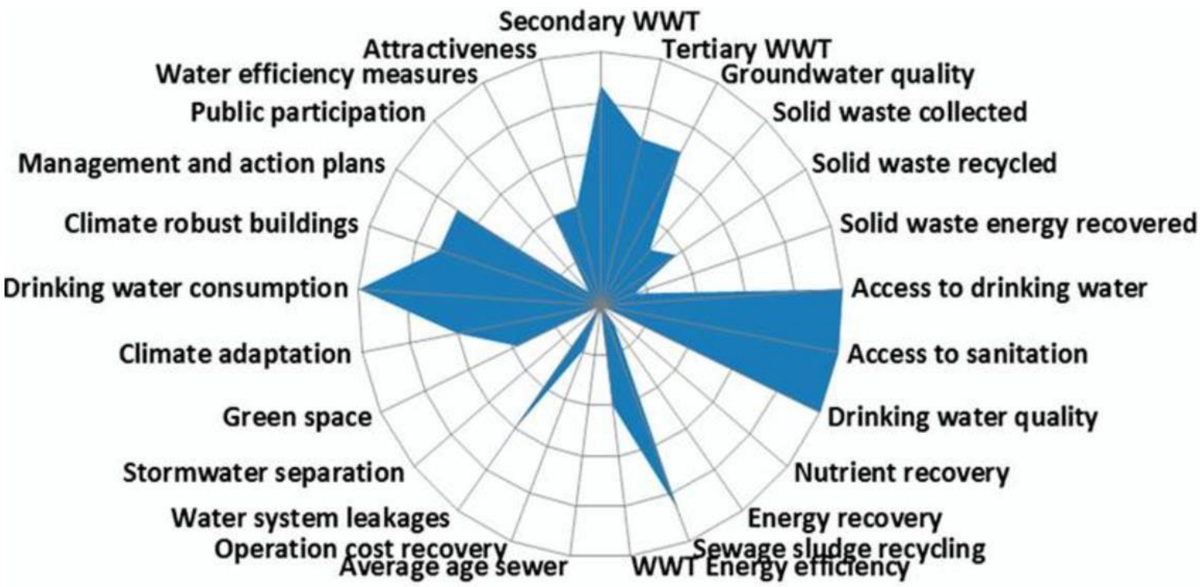

Figure 12 City Blueprint performance framework results for the city of Sabadell, Spain

6.2 Improvement options for Sabadell

In this section, potential improvement options to tackle the key challenges (average age sewer and public participation) of Sabadell are discussed based on the performances of other cities in the world that score high on the indicators (best practices) that need to be improved in Sabadell.

6.2.1 Strengthening public participation

Public participation is the involvement of those affected by a decision in the decision-making process. The City Blueprint indicator represents a national average which does not necessarily reflect the situation in Sabadell. However, at the local scale such an indicator does not exist. Public participation is a process, not a single event. It is considered valuable as it can enhance learning processes, lead to empowerment, improve the quality of decisions, and promote democratic citizenship. Participation is “expected to lead to public support for planning decisions and, as a result, more effective and efficient implementation processes” (Turnhout et al., 2010, p. 1). The most common definition of public participation is “the redistribution of power that enables the have-not citizens, presently excluded from the political and economic processes, to be deliberately included in the future” (Mukhtarovet al., 2018). It is thus important for Sabadell to enhance public participation as it can amongst other things lead to more public support for initiatives such as waste water reuse.

In the following sections we examine the cases of Melbourne (Australia) and Rotterdam (the Netherlands) as these cities scores high on the indicator “public participation” of the City Blueprint.

Melbourne, Australia

In Australia, the value of public participation is increasingly recognised as an essential part of planning projects and making decisions. The City of Melbourne has developed a platform “Participate Melbourne” where people can sign up and join the conversation to influence the plans for their neighbourhood. It is an online community where citizens can have a say on the big issues and future plans of Melbourne. The opinion and ideas of citizens can thus help shape the Council’s decisions on planning and renewal, transport, health, technology and the environment. There is for instance a draft “City River Strategy” that will guide the Council’s future planning of the inner section of the river. It outlines strategic directions and opportunities for how to improve the way the river is used. This strategy is open for community consultation, which means that the Council would like to hear the feedback of citizens and their ideas for its future. Within this consultation there are three ways of sharing feedback: 1) attending an in-person meeting; 2) completing an online survey, and 3) by submitting an idea to the Ideas Forum. All ideas that are submitted are publicly displayed on a forum, where citizens in turn can like the ideas that they support (City of Melbourne, 2019).

Another example of public participation in decision-making is that in 2014 the City of Melbourne implemented a citizen’s jury to make recommendations about the 10 Year Financial Plan. Following discussions, the panel provided a report to the Council. A key feature of the recommendations involved specific initiatives to address climate change and promote long-term liveability, including new strategies for waste management and recycling, drainage, tree coverage and adoption of new technologies. Evaluations showed that jury members supported greater citizen involvement in policy making. Moreover, increased levels of trust and confidence in the Council were reported, as well as a greater satisfaction with future plans for the city of Melbourne (Dean et al., 2016).

Rotterdam, the Netherlands

The municipality of Rotterdam places major importance on public participation as citizens can think along, share ideas and can participate in decisions about the future of the city and specific neighbourhoods. Besides expressing opinions, there is also room to realise ideas and initiatives for the city. There are multiple networking initiatives to share opinions and ideas, such as “BlueCity”. This initiative focuses on the idea of circular entrepreneurship and the circular economy, and gives start-ups space, guidance and a network. There are also citizen initiatives in Rotterdam, including the citizen jury. This jury comprises of 150 citizens and two times per year these citizens give the municipality recommendations on issues the city faces. These opinions and recommendations are subsequently included in a new policy or an adjustment of the existing policy. Public participation is thus very much embedded in Rotterdam's decision-making processes. Another example is that when adjustments are necessary for one of the neighbourhoods of Rotterdam always a process of public participation takes place (City of Rotterdam, n.d.).

6.2.2 Minimising average age sewer

The second challenge of Sabadell is related to the aged sewage infrastructure of the city. Degradation of obsolete sewer pipes can lead to seepage of eroded fine particles to the surrounding soil which may lead to pipe cracking and groundwater pollution. Requirements for water infrastructure investment in developed countries are high (annually 0.35-1.2% of the GDP) and even higher for developing countries (annually 0.71-6.30% of the GDP; Cashman & Ashley, 2008; Koop, 2019). The state of the water infrastructure, indicated by City Blueprint indicators such as the average age of the sewer system, is thus pivotal for the city's financial performance (Koop & Van Leeuwen, 2015b). Only 49% of the water infrastructures in the 75 assessed cities have separated stormwater. Therefore, many cities need to invest substantially in adaptation measures (EEA, 2012; Koop & Van Leeuwen, 201a5). Infrastructure investment shortages in the assessed cities can be observed, for instance by an average leakage rate of 21% and where 7 cities exceed a 40% leakage rate (Koop & Van Leeuwen, 2015a). Infrastructure investments insufficient according to current standards whereas investments have to be increased substantially to enable the necessary climate adaptations for addressing rapid growing population that many cities face (Koop, 2019).

Amsterdam

Urban waste water is domestic waste water or a mixture thereof with industrial waste water, stormwater runoff or other waste water. Amsterdam's waste water is collected and transported to a sewage treatment plant. The municipality is responsible for collecting and transporting waste. There is an extensive sewage system in Amsterdam. Almost all households, businesses and buildings are connected to the sewer system. The functioning of the sewage facilities is regularly tested to ensure that they continue to meet the set standards. In the past 10 years, approximately 62% of the 1,658 km of waste water sewage have been inspected. Given the importance of sewage pumping stations, they have been fitted with a signal. By registering data, maintenance on these pumping stations can be carried out effectively and efficiently (Waternet, 2016).

Amsterdam is also implementing a real-time sewer control system that optimises the storage capacity of the sewer to ensure a constant flow to the waste water treatment plant (De Korte et al., 2009). Moreover, new gutters and stormwater collection systems are constructed to temporarily store rainwater (Van der Hoek et al., 2014). The sewer system in the new neighbourhoods of Amsterdam is different than the sewers in the older neighbourhoods. In new neighbourhoods the rainwater and waste water is collected separately, whereas in older neighbourhoods it flows in the same sewer system. During heavy rainfall the sewer cannot always immediately dispose of all the water. The water is collected in large catch basins, where most of the dirt sinks to the bottom of the basins. When a catch basin is full the excess water flows into the canals. The average age of the sewer system is 28 years and the number of sewer blockages per 100 km is relatively high (Van Leeuwen & Sjerps, 2015). This shows that the city of Amsterdam can also make improvements to make the sewage infrastructure more resilient and sustainable. The local water utility Waternet has set out various objectives in the "Municipal Sewage Plan Amsterdam", related to the sustainability of the sewage system in Amsterdam (Waternet, 2016).

6.3 Opportunities for Sabadell to enhance sustainable urban water management

To improve sustainable urban water management in Sabadell on two aspects (average age sewer and public participation), we examined the best practices of Melbourne, Rotterdam and Amsterdam. In this section, we discuss what is needed for these best practices to be translated to Sabadell.

Public participation

The best practices of Melbourne and Rotterdam show that there are many initiatives to involve citizens and other stakeholders in decision-making processes, either initiated by citizens themselves, organisations or the government. Sabadell can learn from these best practices as in these cases public participation is strongly embedded in policy-making as new plans are not developed without deliberating with citizens. Another lesson comes from the best practice of Melbourne. This city has developed an online platform which consists of surveys and a forum which invites the public to share their opinions and ideas. In this way, multiple stakeholder groups can be targeted at the same time, lowering transaction costs. This platform can be used for a variety of issues, for instance in Sabadell it could ask the opinions of stakeholders on waste water reuse.

Average age sewer

Investments to improve sewage infrastructure is needed to decrease the vulnerability to climate change. There are many urban areas in the world that have the same challenge of reducing the average sewer age. Although there is room for improvement also in the best practice of Amsterdam, the city does score higher than most of the assessed cities. The city has a detailed strategy on sewage networks with clear objectives, regularly maintenance operations are carried out, the quality of waste water is frequently tested, and separate sewage systems are developed in new neighbourhoods. The sewer system of Sabadell is rather old and rainwater is not separated from the sewer. Rainwater may however form an important additional source of water, which is highly important for the city since it is located in a water scarce region (Steflova et al., 2018). To adjust the current sewage systems in Sabadell financial capacity is needed, but financial aspects such as the economic pressure might form a limitation. Sabadell has a relatively low national per capita GDP of 25,684 USD per year (IMF, 2017), which might make it difficult to ask an additional amount of money from citizens to cover the costs of refurbishing the sewage networks. This might be a limitation for Sabadell to translate the practices of Amsterdam to their city. On the other hand, reducing the age of the sewers in Sabadell could result in a reduced rate of leakages which may offset the cost of replacement – this however should be further examined.

7 The role of digital social platforms to improve urban water management

Previous sections examined possible improvement options to enhance the sustainable management of water resources in the Key Demonstration Cities (KDCs) based on best practices. In this section we discuss the potential role of Digital Social Platforms (DSPs), which have been developed within the POWER project, to improve the City Blueprint performances of the KDCs.

DSPs are online platforms which enable two-way communication flows between an authority responsible for urban water management and the users of those water services, as well as other stakeholders involved in urban water management. DSPs may form an important contribution in the efforts of cities to become water-wise and give cities opportunities to face the increasing water-related challenges. The KDCs have their own DSP which focuses on different water challenges: water quality of non-potable reuse of regenerated water (Sabadell), flood risk management (Leicester), reducing drinking water consumption (Milton Keynes), and water conservation (Jerusalem). As mentioned in the introduction (Section 1), these challenges are different to the key challenges discussed in this report. The challenges in this report are solely based on the City Blueprint outcomes and present certain steps that can be taken to realise a more sustainable and resilient water cycle, whereas the water challenges on the DSPs are defined in collaboration with the KDCs.

The current application of the DSP is mainly focused on citizens as information is provided on the water challenges and how to deal with them on household level. In addition to sharing information, users are asked to actively share their experiences and knowledge on the specific water challenge. Users can do this in the form of comments, likes or sharing the discussion on other social media platforms. Furthermore, events and workshops where citizens can participate in are shared on the DSP. The POWER DSP is freely available as open software for cities to apply to their own water sustainability challenge. On the DSP these cities can share information to help create a smarter water community. In addition to citizens, the DSP also has the potential to be a platform to engage with other stakeholder groups, such as professionals and decision- makers. This may enhance a better alignment across sectors and government levels, and the DSP can also stimulate the ability of actors to engage and build trust in order to address the water challenge in an unconventional and comprehensive way. The best practices discussed in the previous sections are an exploration of improvement options, but to effectively translate these options, local professionals and decision-makers should be able to improve the water cycle performances. To successfully target for instance professionals, future DSP applications should be designed according to their needs. The DSP has various opportunities to stimulate engagement with professionals, as for instance for future applications the platform can potentially function as an online working environment for projects. In this way, projects can be coordinated on the DSP, discussions can be performed online as well as it is possible to collectively respond to local, regional and national authorities. Furthermore, events can be organised on the DSP as well.

The DSP can also support in promoting city-to-city learning by sharing best practices on water management. As seen in the previous sections, cities can learn from each other in order to improve performances that cover the urban water cycle. For example, the city of Amsterdam can share ideas and information on the DSP of Leicester on how to make the city rainproof. Whereas the city of Jerusalem might use the DSP as a way of educating citizens on source separating waste and the recycling of waste, for instance by sharing videos of cities that successfully recycle waste. Moreover, the DSP is a tool that can enhance public participation. The best practice of Melbourne (Section 6.2.1) illustrated that online platforms can be used as a way of including stakeholders' opinions in the decision-making process which in turn can lead to increased levels of trust and confidence in the local authority and greater satisfaction with future plans. In this way, for example Sabadell can improve their performance in public participation by actively using the DSP to ask for opinions and ideas from stakeholders, which subsequently could lead to more sustainable management of water resources. Refer again specifically to the POWER BPR and what is included there.

8 Conclusion

The aim of this report was to identify improvement options to further enhance the sustainable management of water resources in each of the POWER Key Demonstration Cities (KDCs), namely Leicester, Milton Keynes, Sabadell and Jerusalem. This report shows that cities can learn from each other. This city-to-city learning may enhance the transition towards water-wise cities. In particular, concrete cases such as the ones highlighted in this report may form a valuable starting point to learn knowledge and experiences from other professionals in other cities. The assessments of the City Blueprint in the four KDCs as well as in 71 other cities indicate that cities can improve their water management through city-to-city learning.

There are many variations in the way cities deal with water-related challenges, which offers key insights for improving their sustainability provided that cities share their best practices. If cities would share their best practices and apply the best practice demonstrated by other cities, theoretically it is possible that the Blue City Index can reach the maximum value of 10 “a water-wise city”. A water-wise city thus scores high on all the water cycle management performance indicators. Learning associations can be used to improve awareness, communication, community involvement, governance and accelerate the transition towards water-wise cities. Water-wisdom can be achieved if there is more emphasis on what cities already know and how this knowledge can effectively be shared and applied in other cities. Improving performances can thus accelerate effective and efficient transitions towards water-wise cities. As mentioned in the discussion, city-to-city learning can be further enhanced by online platforms such as Digital Social Platforms. On these platforms cities can easily share their experiences, knowledge and best practices. The POWER best practice repository is a central point for exchanging and sharing knowledge to tackle water-related challenges, from which other cities in Europe and beyond may learn from.

This report identified potential improvement options for the KDCs based on best practices. The efficacy of best practices depends on contextual factors (a bit more discussion on this theme) There might be some challenges when these improvement options are developed in the KDCs. The city’s water management performance also relates to social, economic and environmental factors. For instance, if cities do not have enough financial capacity it can be questioned if these cities will refurbish their sewage systems as this is a costly measure. Another example is that Scandinavian cities are substantially different to for instance Jerusalem due to various differing characteristics including climate and regulatory systems. Therefore, it is recommended that future research focuses on comparing cities that have similar social, economic and environmental characteristics.

References

Anglian Water. (n.d.). About us. Retrieved August 27, 2019, from https://www.anglianwater.co.uk/about-us/

Anglian Water. (2018). Anglian Water Bioresources Strategy 2020-2045.

Anglian Water. (2019). Renewable Energy. Retrieved August 27, 2019, from https://www.anglianwater.co.uk/in-the-community/protecting-our-environment/climate-change/renewable-energy/

Barton, M. A. (2016). *Nature-based solutions in urban context: a case study of Malmö, Sweden*. Lund: Lund University.

C40 Cities. (2016). C40 Good Practice Guide: Oslo – Waste Management Strategy. Retrieved June 5, 2019, from https://www.c40.org/case_studies/c40-good-practice-guides-oslo-waste-management-strategy

Cascone, S. (2019). Green roof design: state of the art on technology and materials. *Sustainability, 11,* 3020

Cashman, A. & Ashley, R. (2008). Costing the long-term demand for water sector infrastructure. *Foresight 10*, 9–26

Chang, N.B. & Pires, A. (2015). *Sustainable solid waste management: a systems engineering approach.* New Jersey: John Wiley & Sons.

City of Amsterdam. (2010). Amsterdam Waterproof. Report Waternet and Physical Planning Department. Amsterdam: Waternet (in Dutch)

City of Amsterdam. (2015). Sustainable Amsterdam. Amsterdam: City of Amsterdam.

City of Copenhagen. (2014). *Resource and Waste Management Plan 2018*. Copenhagen: City of Copenhagen.

City of Oslo. (n.d.). Waste and recycling statistics. Retrieved June 14, 2019, from https://www.oslo.kommune.no/english/politics-and-administration/statistics/environment-status/waste-and-recycling-statistics/#toc-1

City of Oslo. (2019). Oslo European Green Capital 2019. Retrieved June 17, 2019, from https://www.greencapital2019.com/

City of Melbourne. (n.d.). Green roofs. Retrieved July 4, 2019, from http://urbanwater.melbourne.vic.gov.au/industry/treatment-types/green-roofs/

City of Melbourne. (2019). Participate Melbourne. Retrieved June 19, 2019, from https://participate.melbourne.vic.gov.au/about

City of Rotterdam. (n.d.). Meedenken en meedoen. Retrieved June 19, 2019, from https://www.rotterdam.nl/wonen-leven/participatie/

Copenhagen Capacity. (2012). Danish waste could become new export bonanza. Retrieved June 28, 2019, from http://www.copcap.com/press-room/press-archive/danish-waste-could-become-new-export-bonanza

Cordell, D. & White, S. (2011). Peak phosphorus: clarifying the key issues of a vigorous debate about long-term phosphorus security. *Sustainability, 3*, 2027–2049

Dai, L., Wörner, R. & van Rijswick, H.F.M.W. (2018). Rainproof cities in the Netherlands: approaches in Dutch water governance to climate-adaptive urban planning. *International Journal of Water Resources Development*, *34*, 13600648

De Jong, R. (2017). *Governance of phosphate recovery from wastewater in Amsterdam*. Amsterdam: University of Amsterdam.

De Korte, K., Van Beest, D., Van Der Plaat, M., De Graaf, E. & Schaart, N. (2009). RTC simulations on large branched sewer systems with SmaRTControl. *Water Science & Technology*, *60*(2), 475-482

Dean, A.J., Fielding, K.S., Ross, H. & Newton, F. (2016). *Community engagement in the water sector: an outcome-focused review of different engagement approaches.* Melbourne: Cooperative Research Centre for Water Sensitive Cities.

EC. (n.d.). Application form for the European Green Capital Award 2019. Retrieved June 18, 2019, from http://ec.europa.eu/environment/europeangreencapital/wp-content/uploads/2017/06/Indicator_7_Waste_Production_and_Management.pdf

EC. (2008). Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives.

EC. (2011). Communication from the commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Roadmap to a Resource Efficient Europe. /* COM/2011/0571 final */

EC. (2014). The European critical raw materials review. MEMO/14/377 26/05/2014. Retrieved July 4, 2019, from http://europa.eu/rapid/press-release_MEMO-14-377_en.htm

EC. (2015). European innovation partnership on water. City blueprints action group, Brussels, Belgium. Retrieved June 4, 2019, from http://www.eip-water.eu/City_Blueprints

EC. (2016). Green infrastructure. Retrieved June 2, 2019, from http://ec.europa.eu/environment/nature/ecosystems/index_en.htm

EEA. (2012). *European Environment Agency: Urban adaptation to climate change in Europe: Challenges and opportunities for cities together with supportive national and European Policies. (EEA Report 2/2012).* Copenhagen: European Environment Agency

Elsevier. (n.d.). Scopus. Retrieved August 26, 2019, from https://www.scopus.com/search/form.uri?display=basic

EU. (n.d.). Oslo takes an integrated approach to treat waste into circular bio-resources. Retrieved June 19, 2019, from https://circulareconomy.europa.eu/platform/en/good-practices/oslo-takes-integrated-approach-treat-waste-circular-bio-resources

Fruergaard, T., Astrup, T. & Ekvall, T. (2009). Energy use and recovery in waste management and implications for accounting of greenhouse gases and global warming contributions. *Waste Management and Research, 27,* 724-737.

GENCAT. (2018). Sabadell. Retrieved August 26, 2019, from https://www.idescat.cat/emex/?id=081878&lang=en

Green Surge. (2015). Malmö, Sweden. Case study city portrait: part of Green Surge study on urban green infrastructure planning and governance in 20 European cities. Malmö: Green Surge.

Heaviside, C., Vardoulakis, S. & Cai, X.M. (2016). Attribution of mortality to the urban heat island during heatwaves in the West Midlands, UK. *Environmental Health, 15*, S27.

HDSR. (n.d.). Afkoppelen. Retrieved May 29, 2019, from https://www.hdsr.nl/werk/schoon-water/rioolwaterzuivering/afkoppelen/ (in Dutch)

IMF (2017) International Monerary Fund: World economic outlook database. Retrieved August 26, 2019, from http://www.imf.org/external/pubs/ft/weo/2013/01/weodata/index.aspx

IPCC. (2006). *CH4 emissions from solid waste disposal. Background paper expert group CH4 emissions from solid waste disposal.* Geneva: Intergovernmental Panel on Climate Change.

IPCC. (2007). *Waste Management, in Climate Change 2007: Mitigation*. Cambridge: Cambridge University Press.

IWA. (n.d.). *The IWA principles for water wise cities*. London: The International Water Association.

Jerusalem Post. (2017). Jerusalem steps up plastic-recycling bid. Retrieved June 17, 2019, from https://www.jpost.com/Israel-News/Jerusalem-steps-up-plastic-recycling-bid-503032

JIPR. (2018). Statistical Yearbook of Jerusalem. Retrieved August 26, 2019, from https://jerusaleminstitute.org.il/en/yearbook/#/147/8254

Jong, R. De. (2017). *Governance of phosphate recovery from wastewater in Amsterdam*. Amsterdam: University of Amsterdam.

Koop, S.H.A., Van Leeuwen, C.J. (2015a). Application of the improved City Blueprint Framework in 45 Municipalities and Regions. *Water Resources Management 29*, 4629-4647.

Koop, S.H.A., Van Leeuwen, C.J. (2015b). Assessment of the Sustainability of Water Resources Management: A Critical Review of the City Blueprint Approach. *Water Resources Management*, 29:5649–5670.

Koop, S.H.A., Van Leeuwen, C.J. (2017). The challenges of water, waste and climate change in cities. Environ*ment, development and sustainability* 19 (2), 385-418.

Koop, S.H.A., Monteiro Gomes, F., Schoot, L.G.L., Dieperink, C., Driessen, P.P.J. & Van Leeuwen, C.J. (2018). Assessing the capacity to govern flood risk in cities and the role of contextual factors. *Sustainability, 10*(8), 2869

Koop, S.H.A. (2019). *Towards water-wise cities: global assessment of water management and governance capacities.* Retrieved August 27, 2019, from https://www.kwrwater.nl/actueel/voldoende-water-en-droge-voeten-in-de-stad/

Kruuse, A.F., Verchou, A. (2005). *Wit Transactions on Ecology and the Environment, 81,* 171-179.

Labatut, R.A. & Pronto, J.L. (2018). *Chapter 4: Sustainable Waste-Energy Technologies: Anaerobic Digestion. In: Sustainable Food Waste-to-Energy Systems.* London: Elsevier.

LCC. (n.d.). About Leicester. Retrieved May 8, 2019, from https://www.leicester.gov.uk/your-council/about-us/about-leicester/

LCC. (n.d.). Awards. Retrieved August 26, 2019, from https://www.leicester.gov.uk/leisure-and-culture/parks-and-open-spaces/awards/

LCC. (2012). Surface Water Management Plan. Leicester: Leicester City Council.

LCC. (2015). Local Flood Risk Management Strategy. Leicester: Leicestershire County Council.

Lehner, M. (2017). The Malmö tools: green space factor and the green points system. Retrieved July 2, 2019, from https://nextcity.nl/the-malmo-tools-green-space-factor-and-the-green-points-system/

Ligtvoet, W., Hilderink, H., Bouwman, A., Van Puijenbroek, P., Lucas, P. & Witmer, M. (2014). *Towards a world of cities in 2050 – an outlook on water-related challenges. Background report to the UN-Habitat Global Report.* The Hague: PBL Netherlands Environmental Assessment Agency

Luccarelli, M. & Røe, P.G. (2013). *Green Oslo: Visions, Planning and Discourse (Urban Planning and Environment).* London: Routledge

Maktabifard, M., Zaborowska, E. & Makinia, J. (2018). Achieving energy neutrality in wastewater treatment plants through energy savings and enhancing renewable energy production. *Review in Environmental Science and Bio/Technology, 17*(4), 655-689.

Manfredi, S., Tonini, D., Christensen, T.H. & Scharff, H. (2009). Landfilling of waste: Accounting of greenhouse gases and global warming contributions. *Waste Management and Research*, *27*, 825–836

McKinsey. (2013). *Infrastructure productivity: How to save $1 trillion a year*. London: McKinsey & Company

Melbourne Water. (2013). *Stormwater strategy: A Melbourne Water strategy for managing rural and urban runoff.* Melbourne: The Victorian Government and Melbourne Water

Melbourne Water. (2016). *Guidelines for stormwater harvesting on Melbourne Water drainage assets.* Melbourne: The Victorian Government and Melbourne Water

Melbourne Water (n.d.). Stormwater harvesting. Retrieved May 14, 2019, from https://www.melbournewater.com.au/planning-and-building/stormwater-management/stormwater-harvesting

Mukhtarov, F., Dieperink, C. & Driessen, P.P.J. (2018). The influence of information and communication technologies on public participation in urban water governance: a review of place-based research. *Environmental Science & Policy, 89,* 1-9

Muznik, S. (n.d.). 9 reasons why we better move away from waste-to-energy, and embrace zero waste instead. Retrieved June 17, 2019, from https://zerowasteeurope.eu/2018/02/9-reasons-why-we-better-move-away-from-waste-to-energy-and-embrace-zero-waste-instead/

Norton, B.A., Coutts, A.M., Livesley, S.J., Harris, R.J., Hunter, A.M. & Williams, N.S.G. (2014). Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. *Landscape and Urban Planning, 134,* 127-138

Nutrient Platform. (n.d.). Fosfaat uit afvalwater Amsterdam. Retrieved June 2, 2019, from https://www.nutrientplatform.org/succesverhalen/waternet/ (in Dutch)

OECD. (2013). *Environment at a glance 2013: OECD indicators*. Paris: OECD Publishing.

OECD. (2015). *Water and cities: Ensuring sustainable futures*. Paris: OECD Publishing.

ONS. (2011a). Leicester Local Authority. Retrieved August 26, 2019, from https://www.nomisweb.co.uk/reports/localarea?compare=E06000016

ONS. (2011b). Milton Keynes Local Authority. Retrieved August 26, 2019, from https://www.nomisweb.co.uk/reports/localarea?compare=E06000042

Rahmasary, A.N., Robert, S., Chang, I.S., Jing, W., Park, J., Bluemling, B., Koop, S. & Van Leeuwen, C.J. (2019). Overcoming the challenges of water, waste and climate change in Asian cities. *Environmental Management, 63*(4), 520-535.

Ruhm, D. (2016). *Norway now has the most efficient recycling plant on Earth*. Retrieved June 13, 2019, from https://www.goodnet.org/articles/norway-now-has-most-efficient-recycling-plant-on-earth

Scandinavian Biogas. (n.d.). Södertörn, Sweden. Retrieved June 18, 2019, from http://scandinavianbiogas.com/en/project/sofielund-3/

SGRI. (n.d.). About green roofs. Retrieved June 2, 2019, from https://greenroof.se/en/about-green-roofs/

SCS. (n.d.). Waste to energy. Retrieved June 19, 2019, from https://smartcitysweden.com/focus-areas/waste-to-energy/

State Government of Victoria. (2015). Stormwater harvesting and use. Retrieved June 4, 2019, from https://www.epa.vic.gov.au/your-environment/water/stormwater/stormwater-harvesting-and-use

Statistics Norway. (2018). Population and land are in urban settlements. Retrieved August 26, 2019, from https://www.ssb.no/en/befolkning/statistikker/beftett

Steflova, M., Koop, S.H.A., Elelman, R., Vinyoles, J. (2018). Governing Non-Potable Water Reuse to Alleviate Water Stress: the Case of Sabadell, Spain. *Water*, *10*(6), 739

Stockholm Vatten Och Afvall (n.d.). Waste management plan for Stockholm 2017-2020. Retrieved June 18, 2019, from https://www.stockholmvattenochavfall.se/globalassets/pdf1/riktlinjer/avfall/avfallsplan/sva072-avfallsplan_en.pdf

Storm. (2019). Storm sewer vs. sanitary sewer. Retrieved May 14, 2019, from https://www.azstorm.org/stormwater-101/storm-vs-sanitary-sewer

STW. (2007). Focus on water. Strategic Direction Statement 2010-2035. Coventry: Severn Trent Water.

STW. (2015). Our Commitments. Better value, better services and a healthier environment: Severn Trent Water's business plan commitments for 2015 to 2020. Coventry: Severn Trent Water.

Susdrain. (n.d.). Susdrain SuDS Awards entries. Retrieved August 26, 2019, from https://www.susdrain.org/community/SuDS_Awards_entries

Strzelecka, A., Ulanicki, B., Koop, S., Koetsier, L., Van Leeuwen, K. & Elelman, R. (2017). Integrating water, waste, energy, transport and ICT aspects into the smart city concept. *Procedia Engineering*, *186*, 609-616.

Turnhout, E., Van Bommel, S. & Aarts, N. (2010). How participation creates citizens: participatory governance as performative practice. *Ecology and Society, 15*(4), 26-41.

UN. (2018). 68% of the world population projected to live in urban areas by 2050, says UN. Retrieved January 23, 2019, from https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html

UNEP. (n.d.). About water. Retrieved June 1, 2019, from https://www.unenvironment.org/explore-topics/water/about-water

UNDESA. (n.d.). International Decade for Action 'Water for Life' 2005-2015. Retrieved October 23, from http://www.un.org/waterforlifedecade/water_and_sustainable_development.shtml

University of Leicester. (2015). New state-of-the-art University of Leicester building to achieve record level of energy efficiency. Retrieved August 26, 2019, from https://www2.le.ac.uk/offices/press/press-releases/2015/may/new-state-of-the-art-university-of-leicester-building-to-achieve-record-level-of-energy-efficiency

UN Water. (n.d.). Water and Urbanization. Retrieved June 4, 2019, from https://www.unwater.org/water-facts/urbanization/

UN Water. (2018). Progress on integrated water resources management – global baseline for SDG indicator 6.5.1. Retrieved June 20, 2019, from https://www.unwater.org/publications/progress-on-integrated-water-resources-management-651/

Urban Waste. (n.d.). Copenhagen. Retrieved June 4, 2019, from http://www.urban-waste.eu/520-2/

Van der Hoek, J.P., De Fooij, H. & Struker, A. (2016). Wastewater as a resource: strategies to recover resources from Amsterdam's wastewater. *Resources, conservation and recycling, 113,* 53-64.

Van der Hoek, J.P., Hartog, P. & Jacobs, E. (2014). Coping with climate change in Amsterdam - A watercycle perspective. *Journal of Water and Climate Change, 5,* 61-69

Van Leeuwen, C.J & Sjerps, R.M.A. (2015). The City Blueprint of Amsterdam: an assessment of integrated water resources management in the capital of the Netherlands. *Water Science & Technology: Water Supply, 15*(2), 404-410.

Van Leeuwen, C.J., de Vries, E. & Koop, S. (2018). The energy & raw materials factory: role and potential contribution to the circular economy of the Netherlands. *Environmental Management*, *61*, 786-795

Vattenfall. (n.d.). Waste. Retrieved June 19, 2019, from https://group.vattenfall.com/what-we-do/our-energy-sources/waste

Waternet. (2016). Gemeentelijk rioleringsplan Amsterdam. Amsterdam: Waternet.

Waternet. (2019). Thermische energie. Retrieved June 3, 2019, from https://www.waternet.nl/innovatie/co2-reductie/thermische-energie/

Waternet. (n.d.). Combined sewer system. Retrieved May 8, 2019, from https://www.waternet.nl/en/our-water/sewer-water/combined-sewer-system/

Waternet. (n.d.). Average water use. Retrieved August 26, 2019, from https://www.waternet.nl/en/our-water/our-tap-water/average-water-use/

Wavin. (2017). Pros and Cons of separating rainwater from sewers to prevent sewer overflow in urban areas. Retrieved May 29, 2019, from https://www.wavin.com/en-en/News-Cases/News/Pros-and-Cons-of-separating-rainwater-from-sewers-to-prevent-sewer-overflow-in-urban-areas

Zeeman, G. (n.d.). Recovering nutrients from waste water. Retrieved June 3, 2019, from https://www.wur.nl/en/show/Recovering-nutrients-from-waste-water.htm

Zimmermann, E., Bracalenti, L., Piacentini, R. & Inostroza, L. (2016). Urban flood risk reduction by increasing green areas for adaptation to climate change. *Procedia Engineering, 161*, 2241-2246.