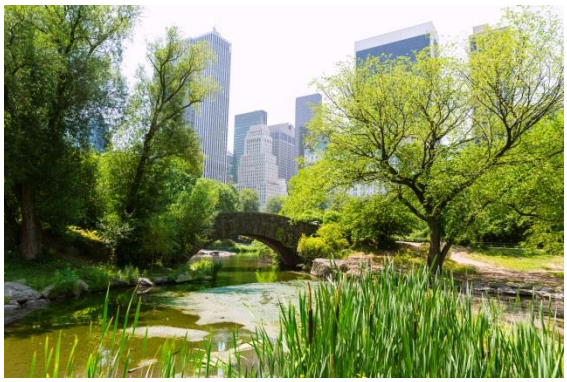
# Towards Water Smart Cities

## *Climate adaptation is a huge opportunity to improve the quality of life in cities*

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This project was funded by:

- EIT Climate KIC, Pathfinder Ideator Programme
- Amsterdam Institute for Advanced Metropolitan Solutions
- Dutch Ministry of Economic Affairs (KB 5200042865)

Illustration made by Natasha de Sena MSc. – Wageningen Environmental Research

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This report is also published as report number 2787 of Wageningen Environmental Research (Alterra).

December 2016

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# Summary

## Key messages

- **The world is urbanising and climate changing will have large impact on cities**
  - In 2050 worldwide over 6 billion people will live in cities. Europe is one of the most urbanised continents in the world. More than two thirds of the European population lives in urban areas and this share continues to grow.
  - City densification is both, an opportunity for economic growth and a threat for liveability. Urban growth will put large pressure on the availability of water, food and energy. Climate change will put more pressure on cities by increasing the risk for floods, droughts and heat waves. The sense of urgency for climate mitigation and adaptation is growing.

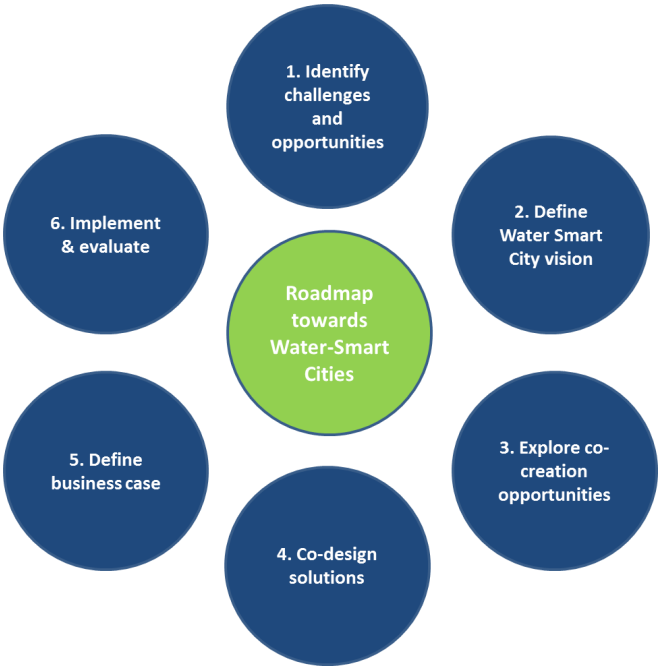
- **Water plays a central role in sustainable urban development. Cities around the world face great challenges with water –too much and/or too little**
  - The World Economic Forum Global Risk Report identified water crises – droughts and floods, sea level rise and pollution – as the risk with the largest expected global impact over the coming decades.
  - Flood events are occurring more frequently all over Europe causing major damage in urban areas. The frequency and intensity of rain events will increase in the future.
  - Besides flood risk, water shortage is an increasing concern. A recent global study shows that 1 in 4 cities already is already water stressed and climate change and urbanisation will increase the risk for water shortage in peri-urban river basins (McDonald et al., 2014).
  - Resources are limited while at the same time demand for these resources is increasing due to the larger number of people living in urban areas. Water, energy and materials sources need to be used more efficient, and where possible recycled and reused. Water is essential for life, and therefore our most precious resource.
  - These challenges ask for a systemic approach and a transition in urban planning and urban water management. We have to rethink the way we deal with water in our cities to create green, resilient and circular cities, so called Water Smart Cities.

- **The Water Smart City approach integrates urban planning and water management to increase climate resilience + creating value for citizens**
  - A transition is needed to (re)design cities from drained cities towards water smart cities in order to restore the natural drainage capacity of cities and close the urban water cycle. Every drop of water in our cities has a value. A Water Smart City treats water as a resource instead of as a nuisance. Collaboration between businesses, public authorities, researchers and citizens plays a unique part to ensure rapid transition.
  - Smart combinations of technical, civil engineering and nature based solutions for climate adaptation and the transition to the Water Smart City approach will create large business and innovation opportunities.

- **Integrating urban development and climate adaptation offers huge opportunities to improve the quality of urban life**
  - Sustainable urban infrastructure is receiving increasing attention from the private sector, governments and researchers.
  - Worldwide US$ 90 trillion will be invested in urban infrastructure over the next 15 years to replace ageing infrastructure and realise urban densification (GCEC, 2016).
  - Every redevelopment project offers huge opportunities to create value and synergy with climate mitigation and adaptation goals by applying the Water Smart City approach.

- **There is a strong need for an evidence base to show that Water Smart City approaches are more sustainable, create more benefits and therefore provide a solid business case**
  - Climate adaptation should be executed on street/district level, the smallest building block of a city. With co-creation opportunities, climate adaptation measures are easy implementable, by coupling these measures to urban development programmes (renovation of sewers, roads, housing projects).
  - As all transitions, the transition towards Water Smart Cities faces many barriers. Sectoral thinking and finance, lack of awareness, short term investments versus long term benefits, current regulations supporting conventional approaches and lack of knowledge about cost and benefits all hinder more integrated approaches.
  - For a solid business case, there is a need for evidence based measures. Living labs, where the effectiveness and cost-benefits of measures are monitored in several European cities will contribute to this and show that the Water Smart City approach creates value for citizens, companies and the environment.

- **Roadmap: 6 steps towards Water Smart Cities**



1. **Identify challenges and opportunities:** At first the challenges and opportunities related to the water system and city liveability need to be identified. These can be related to different ambitions and goals that the city has defined, for example in the area of health, climate, energy, safety, and poverty reduction. From this analysis a new hydro-social contract between the city and the citizens and business can be defined.

2. **Define WSC vision***:* A water smart city vision needs to be defined for the city. Each city has its specific challenges and opportunities related to the natural system and liveability. Therefore each city needs to set up a vision "when are we a water smart city?" and strive to share and embed this vision among all actors.

3. **Explore co-creation opportunities:** In this step, we are moving towards the implementation of WSC. Different pathways can be followed. Actions can be linked to already planned actions/projects, making small adjustments to a plan in order to make it more water smart, or a new trajectory is needed to be set up. Visualise timeline infrastructural projects and investigate co-creation possibilities by linking climate adaptation goals with planned infrastructural projects

4. **Co-design solutions:** In this step the best (combination of) possible measures are analysed to determine the optimal way and possible pathways (a specific project or a new trajectory) to reach the cities' ambitions. This can be best integrated within the quadro-helix model (network of government, citizens, business, and institutes; and with experts from different disciplines).

5. **Define Business case:** From the proposed combination of possible measures (scenarios), the best (most optimal) business case should be chosen. Each scenario has its benefits and disadvantages in relation to its performance (incl. flexibility), costs and value, and risks over a certain timespan. All these factors should be balanced with each other to determine the most optimal business model, which will be part of the project plan to implement the measures.

6. **Implement & evaluate** (Continuous) implementation of WSC measures, celebrate and learn from them and where needed adjust the process or ambitions until it is business as usual (plan-do-check-act). Through pilots (set up from scratch), living labs (in real areas), small scale or large scale project, co-creation or new trajectory. Important to learn from the projects, proof of concept, and to know if the ambitions are met, therefore monitoring and proper data management and analysis is very important. Continuously improving the evidence base is required.

# 1. Introduction

The world is urbanizing. In 2050 over 6 billion people will live in cities. Europe is one of the most urbanised continents in the world. More than two thirds of the European population lives in urban areas and this share continues to grow. Cities around the world are confronted with many challenges, such as traffic congestion, inadequate energy supply, lack of basic services, informal dwellings, poor management of natural hazards, crime, environmental degradation, climate change, poor governance, urban poverty, informal economy and unplanned development (WEF, 2016).

Urban growth will have large impact on the liveability of cities and will put large pressure on the availability of water, food, energy and materials. Climate change will put even more pressure on cities, as it leads to increased risks of flooding, droughts and heat waves. The sense of urgency for climate mitigation and adaptation is growing.

**Urban development is a huge opportunity to create resilient and liveable cities**
The world is expected to invest around US$90 trillion in infrastructure over the next 15 years. These investments are needed to replace ageing infrastructure in advanced economies and to accommodate growth and structural change in emerging markets and developing countries (Global Commission on the Economy and Climate (GCEC), 2016).

In many countries, urban development has followed a sprawling, inefficient model that leads to congestion, car-dependency, high resource use and resulting high greenhouse gas (GHG) emissions. The world's existing infrastructure – spanning sectors such as energy, public transport, buildings, water supply and sanitation – is estimated to be responsible for 60 per cent of the world's GHG emissions. Yet an alternative is starting to emerge – one focused on compact, connected and sustainable urban growth to create cities that are economically dynamic, vibrant and healthy. Such cities are more productive, socially inclusive and resilient, as well as cleaner, quieter and safer. It is a win-win for the economy, the people and the environment. Sustainable urban infrastructure and development challenges are receiving increasing attention from the private sector, relevant professional associations (e.g. architects, municipal planners and engineers), and researchers (GCEC, 2016).

**Cities around the world face great challenges with water – ranging from too much and/or too little.**
The 2015 World Economic Forum Global Risk Report identified water crises – droughts, floods, sea level rise and pollution – as the risk with the largest expected global impact over the coming decades (WEF, 2015). A recent global study, conducted by McDonald et al. (2014), shows that 1 in 4 cities already is seriously water stressed. Water becomes more and more a scarce resource as a result of urbanisation and increased competition between various uses and economic sectors. Climate change will put more pressure on cities by increasing the risk for floods, droughts and heat waves. These challenges ask for a systemic approach and a transition in urban planning and urban water management. We have to rethink the way we deal with water in our cities and there is a need to (re)design cities from drained cities to green, resilient and circular cities, so called Water Smart Cities (WSC). This report underlines the importance of integrating urban planning and urban water management, gives an overview of barriers and business opportunities and provides a roadmap for creating resilient and liveable Water Smart Cities.

# 2. Transition towards Water Smart Cities

## What is a Water Smart City?

Urbanisation and the impact of climate change call for a new approach to urban water management. We need to find ways where the freshwater resource is cared for in a sustainable way that allows future generations of urbanites to have access to clean freshwater, and where the built-up area of the city with all its physical assets can last and function despite a more extreme climate. Our cities are designed to drain rainwater and waste water outside the city limits, and to import water from rivers and well-fields far outside the city. But every drop of water has a value, and the city should only take a fair share of the locally available freshwater resources. Cities should be considered as catchments. By treating all types of water as a valuable resource, new approaches and opportunities arise; both directly in terms of preserving the freshwater resource and obtaining climate resilience, and indirectly in terms of creating more liveable cities by linking the new water infrastructures to aesthetical and recreational benefits. The idea of the Water Smart City approach is to exploit these opportunities in a smart way.

The Water Smart City approach integrates urban planning and the urban water cycle, and makes a good business out of it for society as a whole. The concept includes integration of stormwater, groundwater, waste water management and water supply to cope with societal challenges related to climate change, resource efficiency and energy transition, to minimise environmental degradation and to improve aesthetic and recreational appeal. This approach develops integrative strategies for ecological, economic, social, and cultural sustainability. Figure 2.1 shows the WSC concept. Systemic WSC innovation opportunities and thus possible positive business cases are mainly achievable in the overlap of the three segments of the urban water cycle (i.e. water supply, surface water runoff and wastewater).

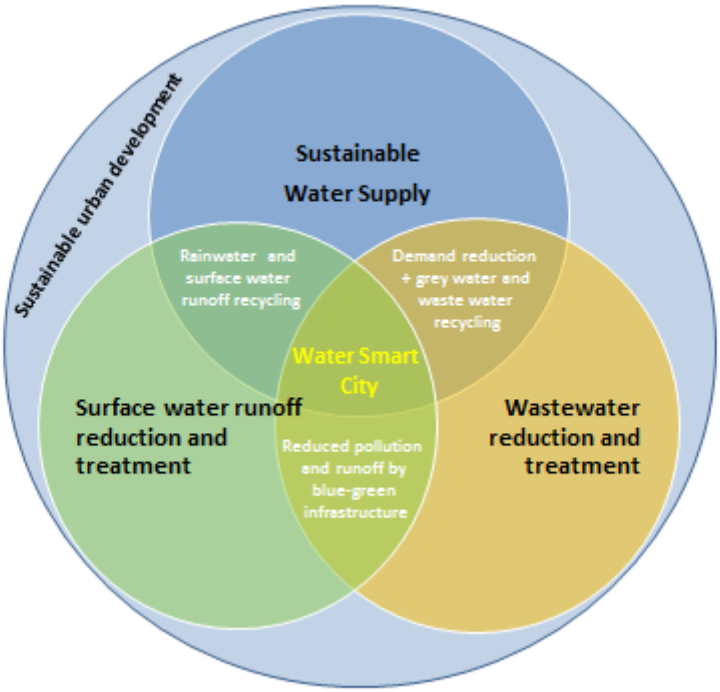



***Figure 2.1: Water Smart City: integrating sustainable urban development and urban water management***

## Water Smart City Approach

Water Smart City approach is a visionary approach to integrate sustainable urban planning and water management that aims to minimise the hydrological impacts of urban development on the surrounding environment. Wong and Brown (2009) describe three pillars for integrating urban development and water management:

1. **Cities as water supply catchments:** Cities would have diverse water resources delivered through an integrated mixture of centralized and decentralized infrastructure at different scales. Hence cities can be granted with flexibility to access to portfolio of sources at least environmental, social and economic costs.

2. **Cities providing ecosystem services and increase liveability:** The integration of urban landscape design and green infrastructure/nature based solutions can help capture the essence of sustainable water management, to some extent mitigate urban heat island effects, contribute to local food production, support biodiversity, and cut down on the greenhouse gas emissions by promoting biking and outdoor recreation. With nature based solutions for water management it is possible to:

    - Protect and enhance natural water systems in urban developments;
    - Integrate storm water treatment into landscape by incorporating multiple use corridors that maximise visual and recreational amenity of developments;
    - Protect water quality draining from urban development;
    - Reduce runoff and peak flows from urban developments by emplacing local detention measures and minimising impervious areas;
    - Integrated solutions for flood reduction, drought and heat mitigation;
    - Add value while minimising drainage infrastructure development costs.

3. **Cities comprising water smart communities and institutions:** Communities live an ecologically sustainable lifestyle and are aware of the ongoing balance and tension between consumption and conservation of the cities natural capital, industry and professional capacity to innovate and adapt as reflective practitioner; and government policies that facilitate the ongoing adaptive evolution of the water sensitive city. All stakeholders are needed to realise Water Smart Cities.

## Transition towards Water Smart Cities

Today there is a clear consensus that an integrated approach to urban water management is needed if the freshwater resource is to be managed in a sustainable way. There is also an emerging consensus of the need for adaptation of cities to climate change. This is all well described by the six states of urban water management suggested by Brown et al. (2009), where the ultimate goal is to establish a Water Sensitive City. The six transition states are illustrated as overlapping rings in Figure 2.2. Most cities in the developed world are in state 3, 4 or 5, while most cities in the developing world are at state 1 or 2. So the question is how all cities can reach the ultimate state, where all the benefits of previous states are obtained together with intergenerational equity and

climate resilience (see movement from left to right in Figure 2.2). This is where the Water Smart City approach comes in, targeting cities in state 3, 4 or 5, with the ambition of facilitating a fast transition to the Water Sensitive City. Cities in these states are all facing the challenge of transforming already fully extended, well-developed water infrastructures with a likewise well-developed institutional set-up for its management, into systems that can take on the current and predicted pressures from both continued urbanization and climate change.

What is smart about the WSC-concept is that it seeks to link the transition to WSC with the strong drivers of 1) private business development, 2) public economic savings due to high indirect benefits 3) the wish of urbanites to dwell in cities that are liveable and attractive from many perspectives, and 4) continuously monitor and evaluate cost and benefits and performance and create an evidence base in order to learn and upscale this approach. This is illustrated by the green arrow in Figure 2.2. Before going into details of these four WSC-drivers, the task of making a city succeed in a transition should be elaborated.

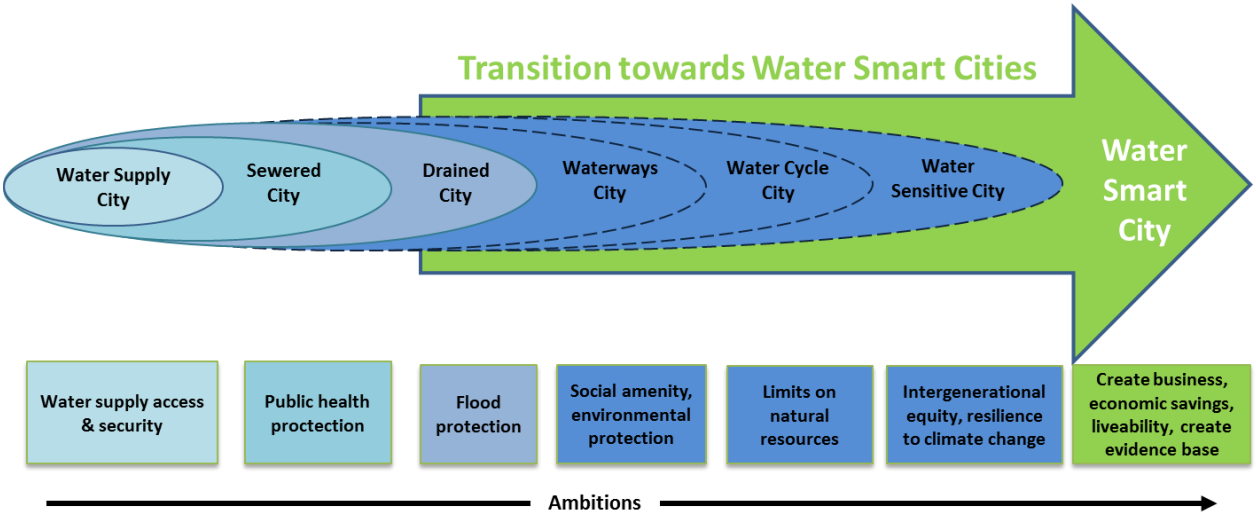



***Figure 2.2: Urban water management is at different levels in different cities (overlapping rings), representing different levels of services to the urbanites, and different levels of sustainable management of the freshwater resource and adaptation to climate change (the boxes below), ranging from a narrow focus on water supply to an advanced focus including intergenerational equity and resilience to future threats from a changing climate. This framework has been published by Brown et al. (2009). The green arrow represents the focus of the Water Smart City concept on how to speed up the transition in a smart way, by simultaneously enhancing liveability and economic development.***

To transform huge systems like the water infrastructures in developed cities is a complex task. The Multi-Level-Perspective (MLP) as suggested by Geels and Schot (2007) provides a useful lens to view the situation through. As further elaborated by Mguni et al. (2015), it operates with three levels as illustrated in Figure 2.3.

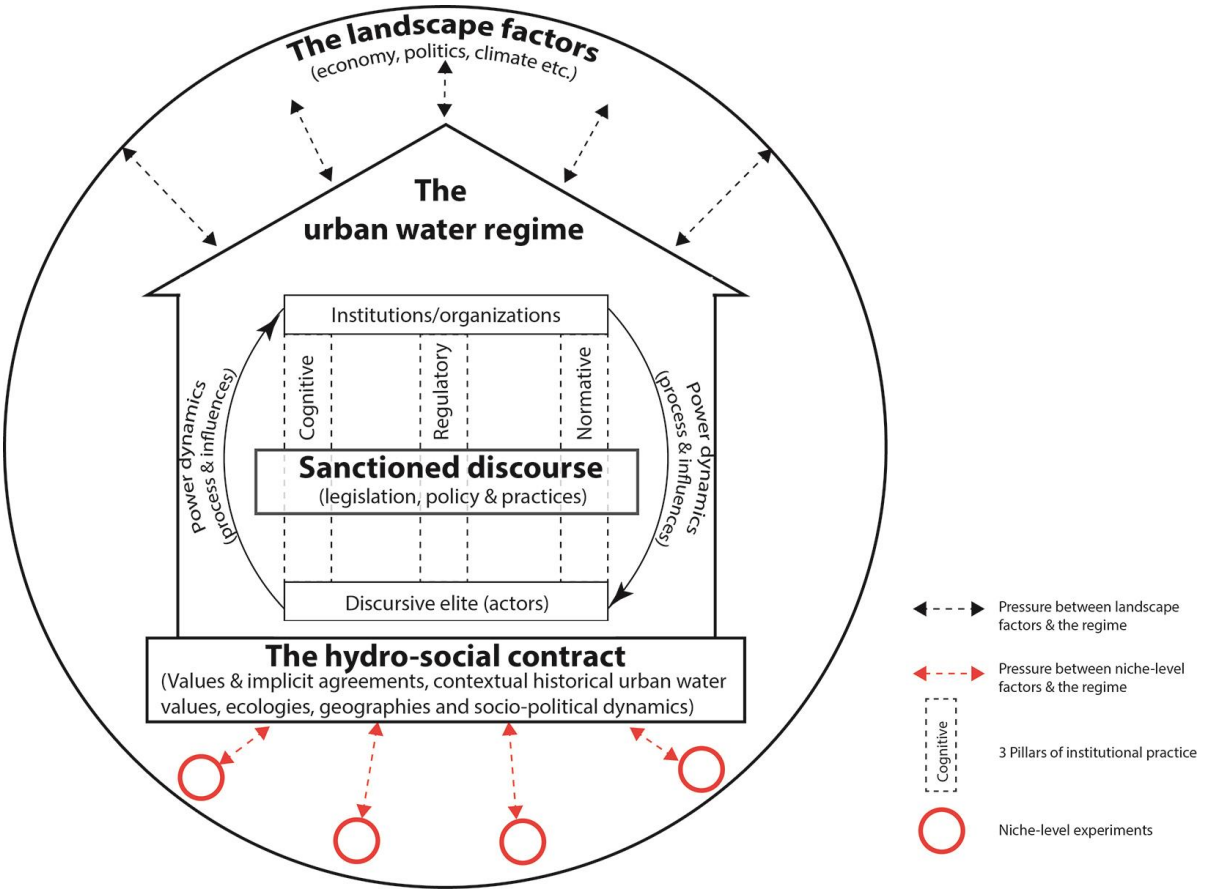



***Figure 2.3: Illustration of the Multi-Level Perspective on transition of large socio-technical systems for the case of urban water systems. From Mguni et al. 2015.***

The 'landscape' is the macro-level and refers to the environmental, social-political and economic pressures acting on the system and calling for the system to change. So it is not the physical landscape, but rather a metaphor for pressures that the current system needs to adapt to, e.g. climate change, urbanization and even the public demand of increasing liveability.

The 'regime', is the meso-level, which refers to the configuration of responsible persons and institutions responsible for the system and the system itself. Thus, the word regime should not be understood with any negative connotations, but rather simply as the existing system, which in Figure 2.3 is illustrated as a house, containing both the physical parts of the system, i.e. pipes, pumps, treatment plants and storages etc., and the persons being responsible for the system, i.e. municipalities, the water authorities and water utility companies. The regime operates according to their sanctioned discourse, which is embedded in the cognitive, normative and regulative conditions (illustrated as the pillars in the house). To obtain a change, and thus a new sanctioned discourse in response to landscape pressures, the discursive elite often plays a role. These are the individuals and institutions that speak with such power that the regime listens.

The last level is the 'niche', which is the micro-level. It reflects the innovations and alternative approaches that develop outside the regime. Sometimes the ideas emerge from the regime itself, but most likely they origin from external actors, e.g. solutions imported from abroad, suggested by academia, or invented by private companies or

individuals. This could include water smart measures. The relation between the regime and the rest of society is in case of urban water management referred to as the 'hydro-social contract' (Wong and Brown, 2009). It is the pervading values and expectations on how water should be managed, and it has typically been shaped throughout the history of the city (ibid). In Figure 2.3 the hydro-social contract is represented as the foundation of the house, i.e. of the regime.

In a market economy like the one ruling in most developed cities private businesses represent a main component for the development and implementation of solutions. This role of **private businesses** can be exploited for rapid dissemination of good solutions on sustainable and resilient cities, but only if the right framing conditions for their operation can be defined and controlled. The challenge is how to ensure that the solutions provided by the companies in fact keep the city on the assumed trajectory towards sustainable and climate resilient development.

**Economic savings** can be a strong policy driver, especially if also the indirect benefits can be monetarized. This requires first of all innovation in the design of urban water management system so that not only water supply, wastewater treatment and flood control is taken care of in a sustainable way, but also the added values in terms of a more green and healthy city with room for new recreational activities. Secondly, to really incorporate such benefits into the city plans and budgets, those benefits need to be documented. This is already difficult when it comes to the value of the direct water-related benefits, e.g. what is the value of being resilient towards a future 100 year rain event? When it comes to indirect benefits it is even more difficult, e.g. how to monetarize the health benefits of having a greener environment, or a less segregated society due to more meeting places, etc.

The driving momentum emerging from urbanites' search for **liveable cities** is directly related to the co-creation power of a city and thus the ability of the city to design, test and implement future solutions. In a wider perspective the ability of the city to brand itself and attract resourceful residents is important for the long term stability of the city.

The need for innovation, and to monitor and evaluate best practices in order to create an **evidence base** for water smart cities is an important driver. In many cities living labs are created to learn about the benefits of systemic water smart solutions and use the generated knowledge for upscaling to national or international level.

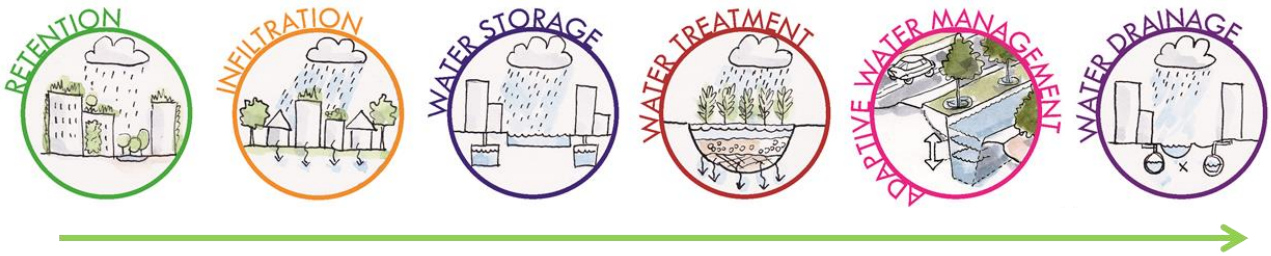
Now, to take advantage of these drivers to speed up transition as suggested in the WSC-concept some guiding frameworks are needed. To suggest a way forward this report presents both lessons learned from existing knowledge on barriers for integrated urban water management and climate resilience, as well as up-to-date information from practitioners from the two forerunner cities Amsterdam and Copenhagen.

# 3. Water Smart City solutions and benefits

## Water Smart City solutions

The WSC concept is enabled by implementing a combination of measures that are based on two strategies:

1. **Restore the natural drainage capacity of cities by introducing nature based solutions**




- **Retention:** Retention of rainwater where it falls to reduce surface run off on e.g. green roofs, (communal) rain gardens, curb extensions.

- **Infiltration:** Improve infiltration capacity of the subsurface by reducing impervious paved surfaces by pervious pavements and creating green infiltration zones allowing rainwater soak into the subsurface and subsequently also restoring ground water (for example green space, bioswales, tree pits)

- **Water storage:** Rainwater harvesting systems collect rainwater from roofs and other paved surfaces for on-site use (for example rainwater tanks, water squares). Storages or detention basins can temporarily hold back water and thus prevent floods

- **Water treatment:** To protect receiving water bodies like streams and groundwater from contamination with pollutants present in the stormwater runoff different treatment elements may be needed. Here filter soil, dual porosity filtration, filter strips, wetlands and wet basins may provide an option. For use of stormwater for supply purposes additional treatment may be needed

- **Adaptive water management:** Water level management by anticipating on long-term weather forecast to increase storage capacity in surface water.

- **Water drainage:** drain excess stormwater and groundwater from pavements and roofs, separately or combined with sewer system, or disconnect from the sewer system.

## 2. Closing the urban water cycle


- **Reduce water use:** Reduce the use of water by citizens and businesses by raising awareness.
- **Improve water efficiency:** Improve the water efficiency of new and existing building by technical measures such as water saving toilets and showers.
- **Water storage:** Storing larger amounts of rainwater from rooftops and paved surface in tanks or retention ponds to prevent pluvial floods and for reuse purposes.
- **Water treatment:** Stormwater treatment or treatment of grey waste water in wetlands or helophyte filters.
- **Water reuse:** Reuse of rainwater and grey waste water in buildings (flushing toilets, washing machines, car washing) or for irrigation.

Table 3.1 presents an overview of WSC measures, differentiated across scales, i.e. building, street/district and city level. Figures 3.2-3.4 and Tables 3.2-3.4 provide a further graphical illustration and details on the WSC measures at building, district and city scale.

***Table 3.1 Overview of WSC measures***

| Scale | Goal | | Measure |
|---|---|---|---|
| **Building level** |  | Reduce the use of water by citizens | • Reduce water use<br>• Raise awareness |
| |  | Improve the efficiency of existing and new buildings | • Water saving / water less toilets<br>• Water saving shower heads<br>• Recycle showers |
| |  | Rainwater retention | • Rooftop retention by blue /green roofs<br>• Green facades / green walls<br>• Raingardens |
| |  | Infiltrate rainwater into the ground | • Disconnect rain pipe<br>• Reduced paved surface<br>• Geocellular / infiltration systems |
| |  | Storing rainwater from rooftops in tanks | • Rainwater tanks<br>• Rainwater storage below buildings<br>• |
| |  | Reuse of rainwater and/or grey waste water | • Rainwater reuse in buildings for toilet flushing + washing machines<br>• Rainwater reuse for irrigation<br>• Reuse of grey waste water for flushing toilets<br>• Reuse of grey waste water for irrigation |
| **Street / District level** |  | Rainwater is retained to reduce the risk of flooding, reduce surface water flows, reduce stress on stormwater sewers, and restore natural hydrology. | • Rooftop retention by blue /green roofs<br>• (Collective) raingardens |
| |  | Infiltrate rainwater into the ground | •<br>• Reduced paved surface<br>• Create more green space<br>• Infiltration zones/trenches<br>• Infiltration sewer / well<br>• Disconnect paved surface from sewer system<br>• Permeable paving<br>• Wadi / bioswales/Tree pit<br>• Geocellular/infiltration systems |

| | | | |
|---|---|---|---|
| |  | Temporary storage/detention of larger amounts of water in order to prevent floods | • Detention basin<br>• Rainwater detention ponds<br>• Water squares<br>• Underground water storage |
| |  | Storm water treatment is often necessary before use in domestic water services or before infiltration into the ground | • Filter soil, bioretention, filter strip<br>• Dual porosity filtration<br>• Greywater treatment like gravel filter/Sand filter/Helophyte filter for treatment of grey waste water |
| |  | Water level management anticipating on weather forecast | • Anticipating water level management to create maximum storage capacity |
| |  | Creating open water systems to store and transport water | • Create more open water<br>• Reconstruct combined sewer system to separate sewer system<br>• Open gutters / Hollow roads<br>• Canal |
| |  | Reuse of treated waste water | • Reuse of grey waste water for irrigation<br>• Waste water effluent reuse |
| **City level** |  | Large scale implementation of water smart measures | • All measures above implemented at large scale<br>• Blue Green corridors<br>• Green ventilation network<br>• Urban forest<br>• Green shores and river banks<br>• Wetland restoration in peri-urban zone |
| |  | Water robust design to prevent damage during floods | • Wetproofing / water resistant construction<br>• Protect critical infrastructure (power plants, water supply, hospitals)<br>• Floodable urban areas (boulevards/cycle path/ roads)<br>• Raising land<br>• Raising ground or floor levels<br>• Construction on piles<br>• Building partly situated in the water<br>• Floating buildings<br>• Evacuation routes at elevated level |

## (Co-)Benefits

The WSC approach can deliver multiple benefits in order to create healthy, resilient and liveable cities compared to conventional drained or sewered city. Some of the most important (co-) benefits are mentioned below and shown in the infographic (Figure 3.1):

- Creating attractive places where people want to live, work and play through the integration of water and green spaces;
- Provide public space for recreation, social interaction and physical activity;
- Increase of property value of buildings close to green space and open water;
- Reduce flood risk and protect and improve the quality of ground- and surface water from polluted run-off;
- Enable a healthy city by reducing urban heat island effect and noise, and improve air quality;
- Improving soil moisture and replenish depleted groundwater levels;
- Supporting and improving local natural habitats and biodiversity;
- Provide society with valuable supply of water;
- Create awareness and improve people's understanding of how run off from their development is being managed and used.

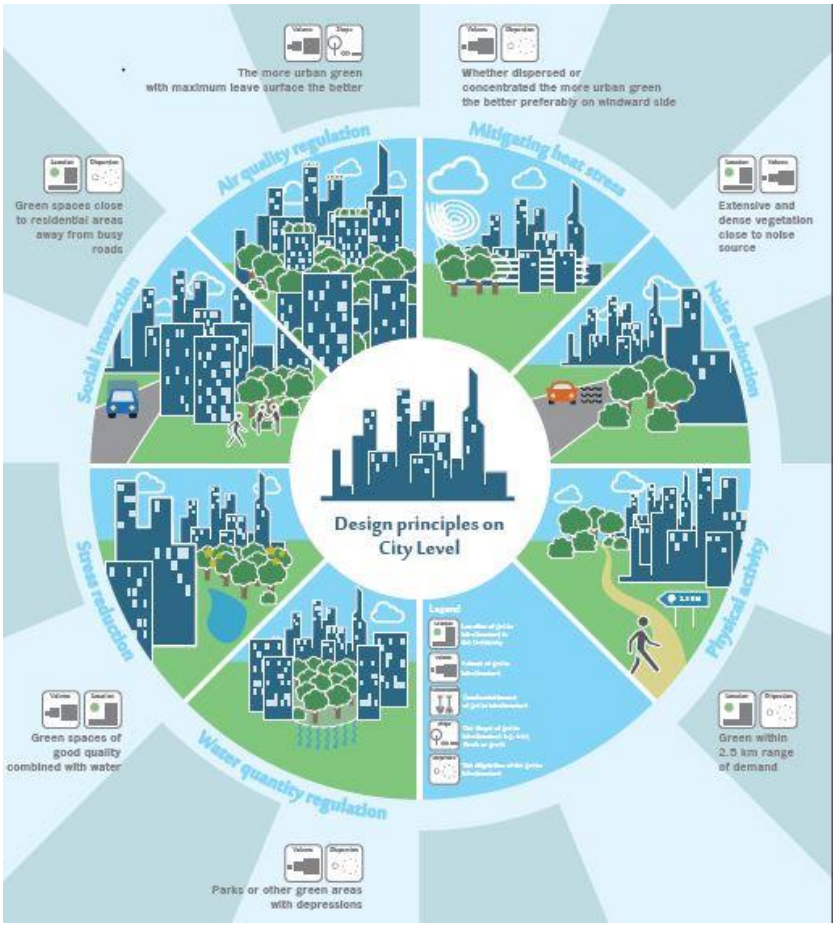



***Figure 3.1 Design principles and benefits of nature based solutions (TO2 Institutes, 2015)***

## How does a Water Smart City look like on building, district and city scale?

### Building scale

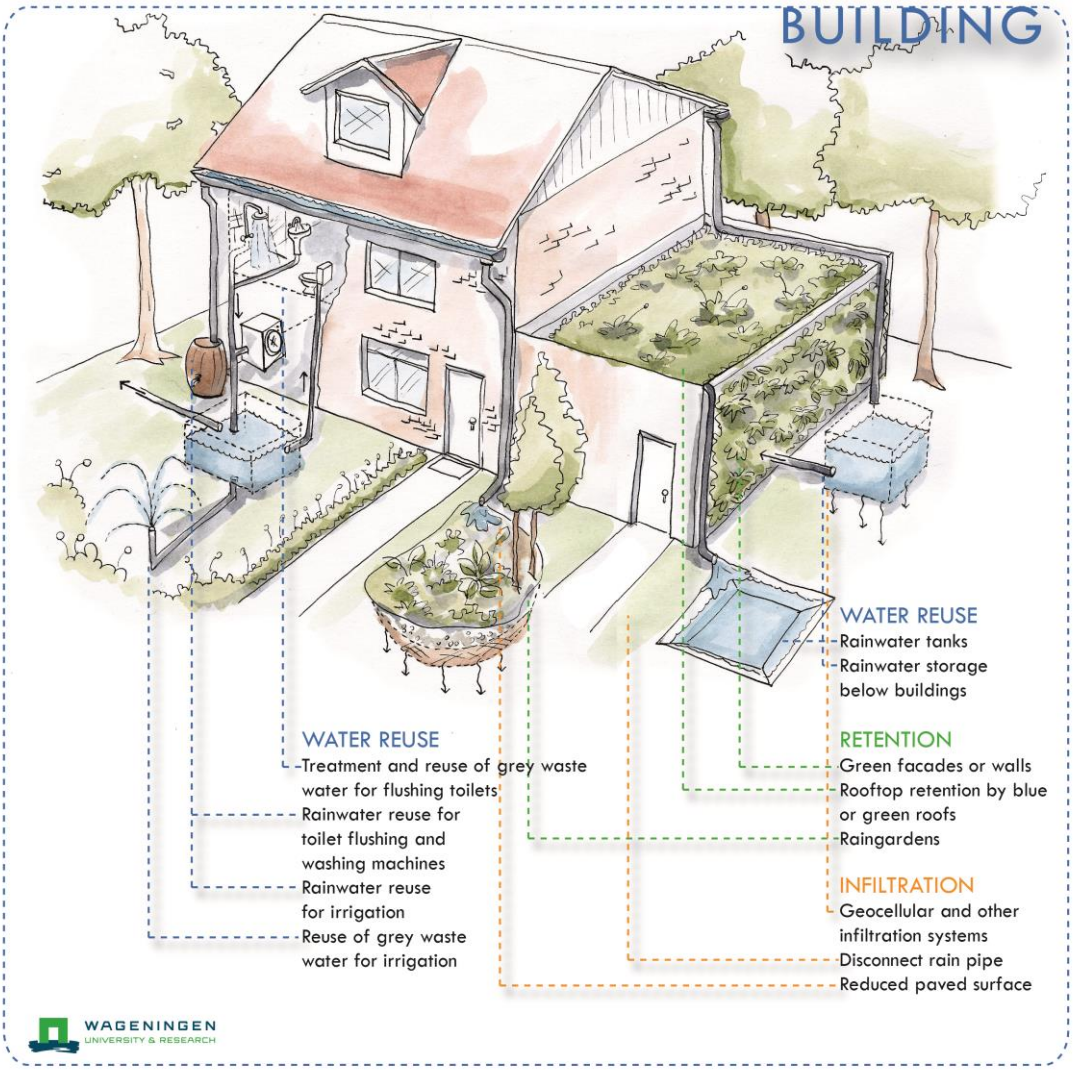



***Figure 3.2 Illustration of possible Water Smart measures on building scale***

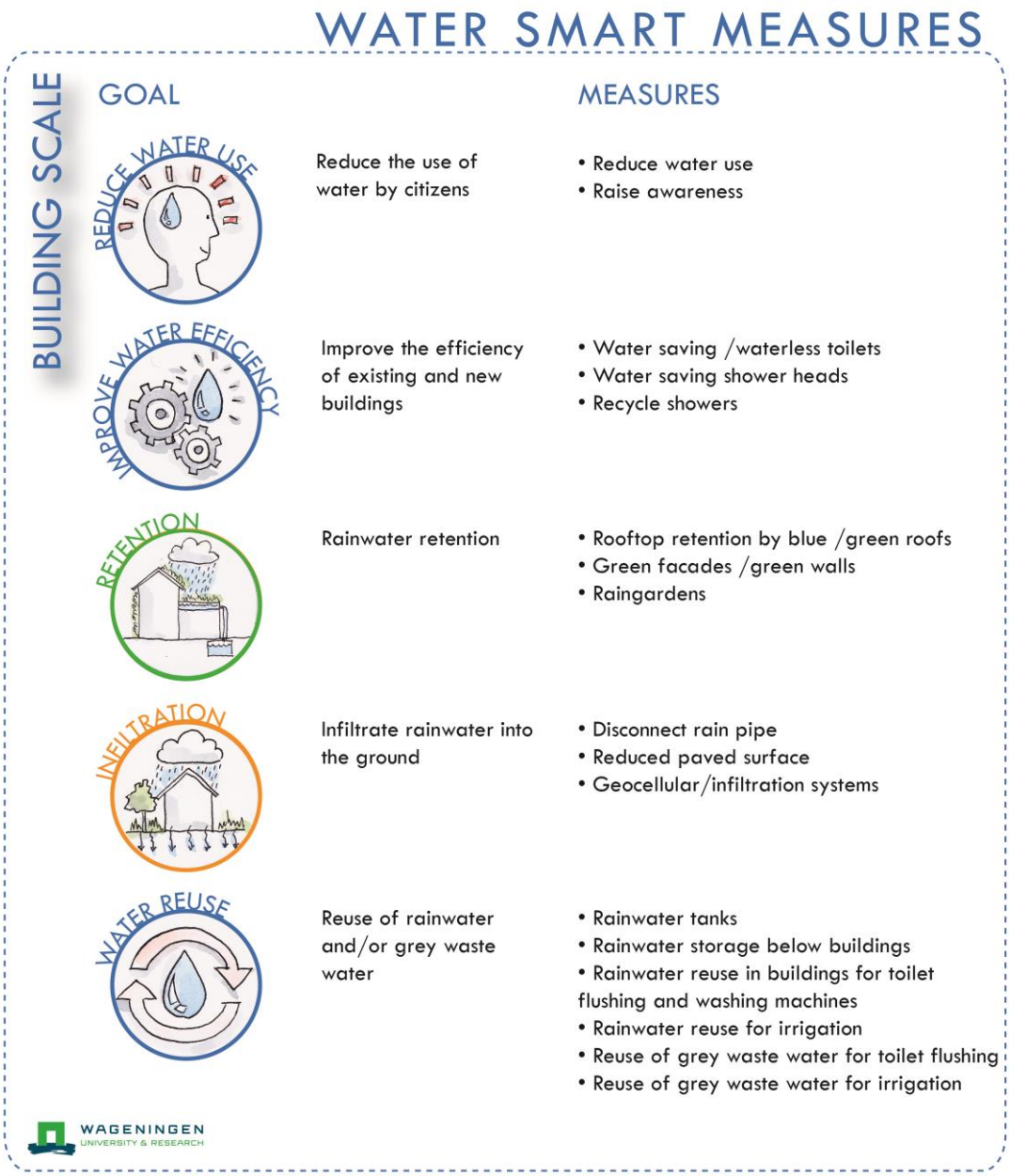



***Table 3.2 Overview of Water Smart measures on building scale***

## District scale

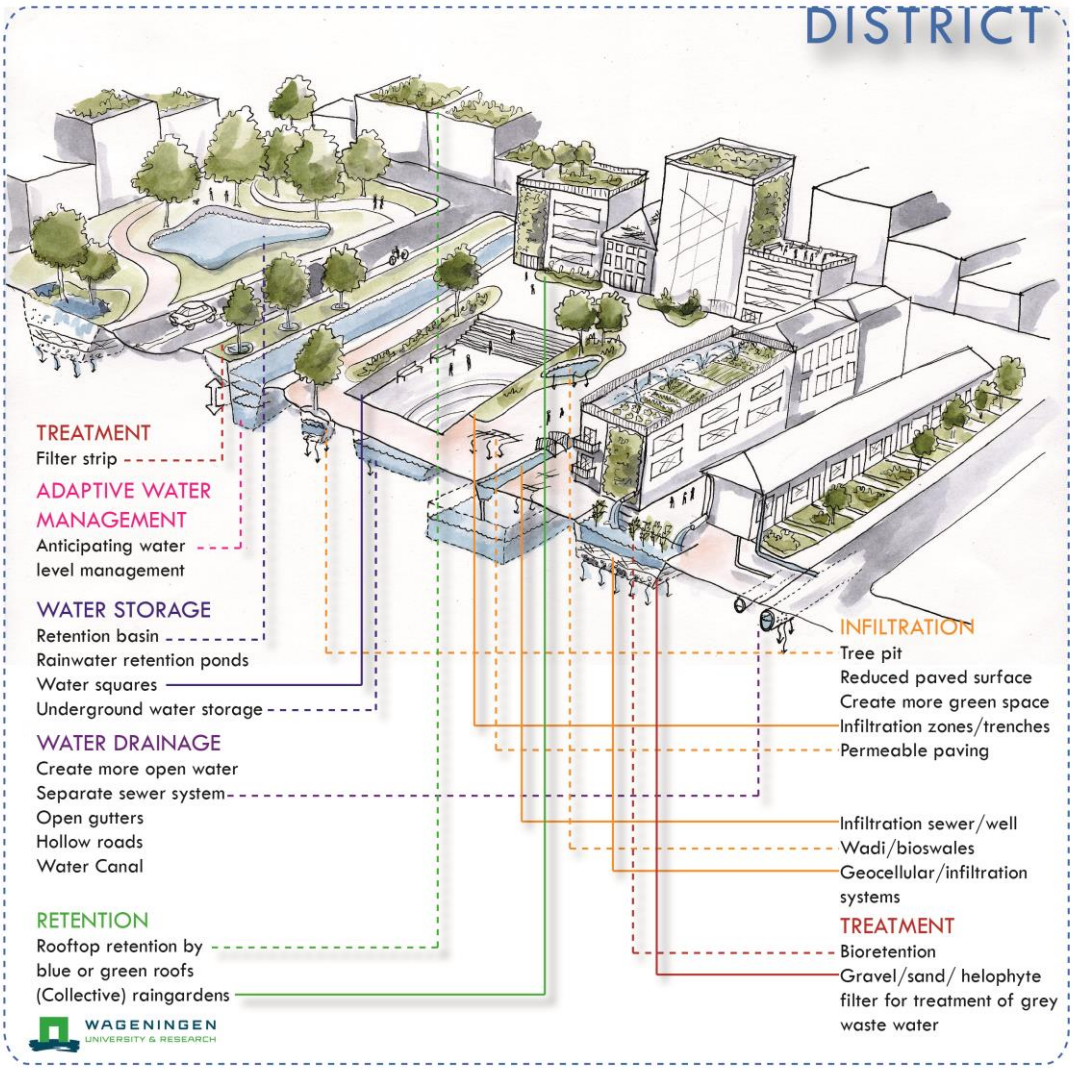



***Figure 3.3 Illustration of possible Water Smart measures on district scale***


***Table 3.3 Overview of Water Smart measures on district scale***

## City scale

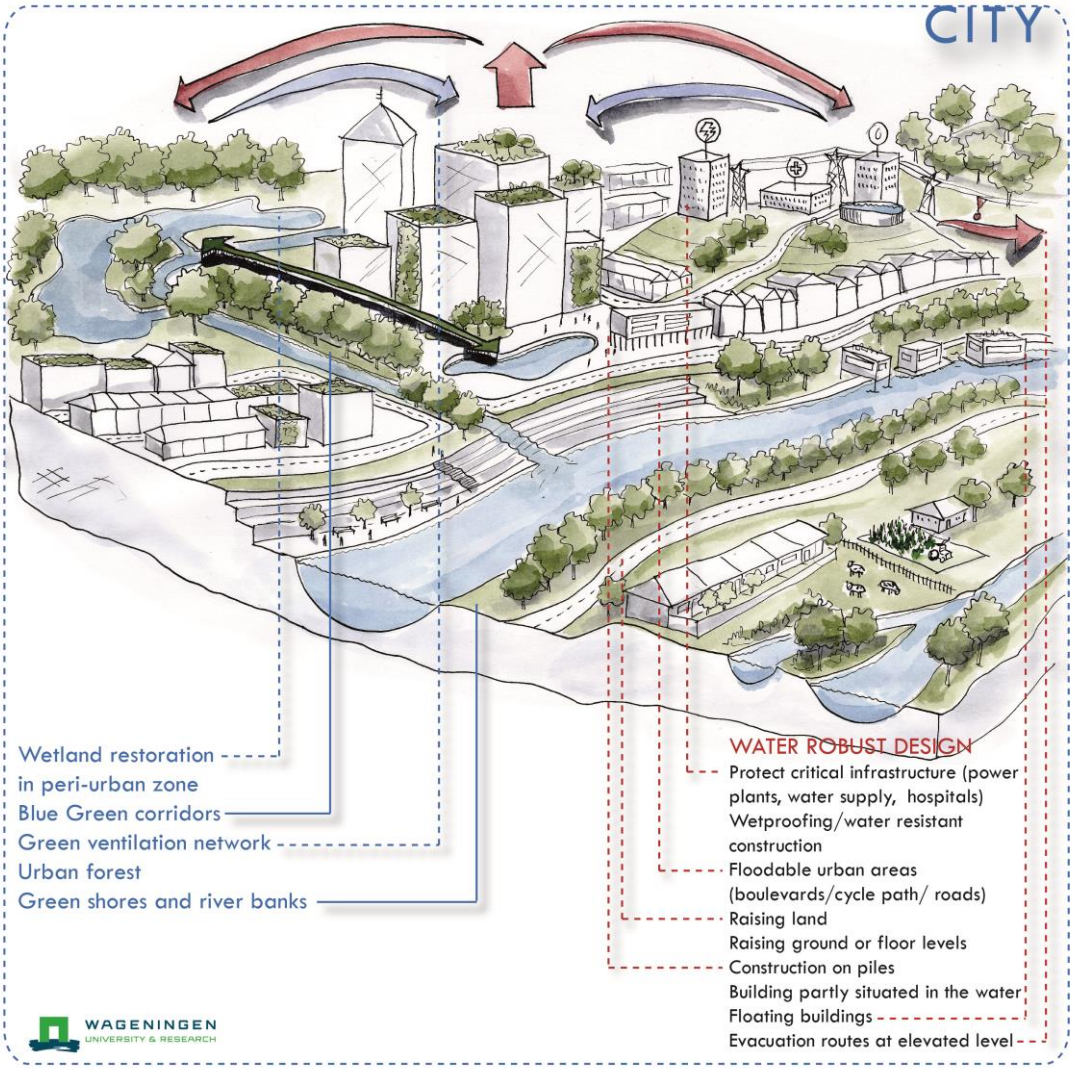



***Figure 3.4 Illustration of possible Water Smart measures on city scale***

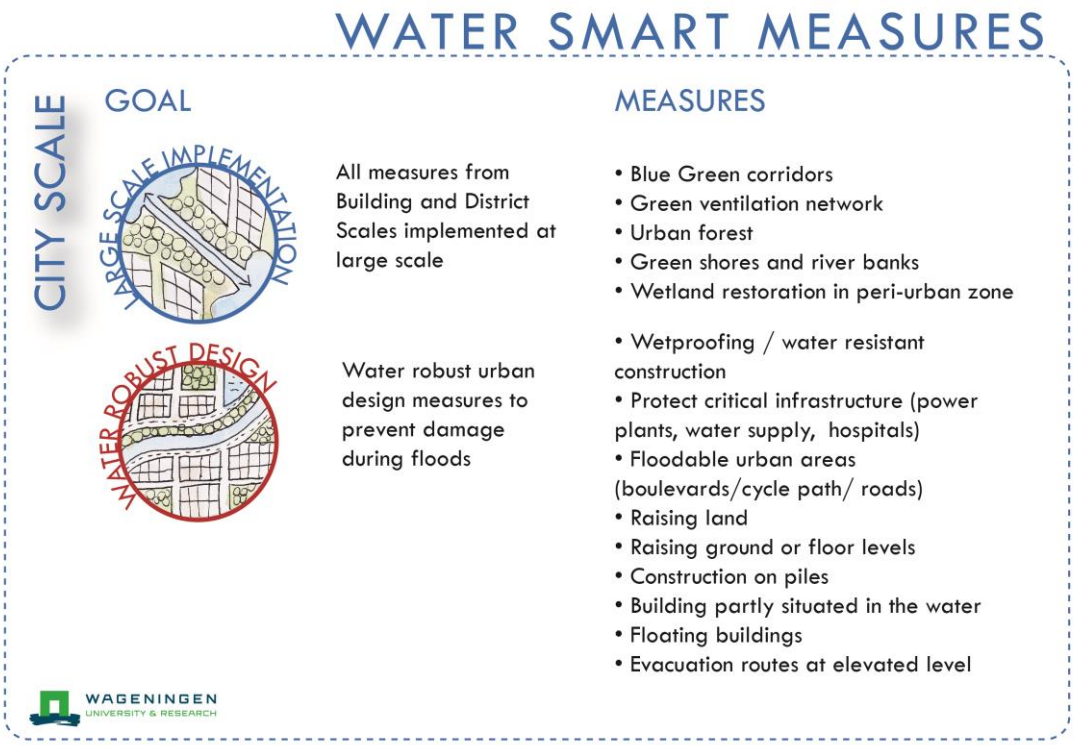



***Table 3.4 Overview of Water Smart measures on city level***

## Increasing business opportunities

To enable the transition towards a WSC, projects at different scales are needed to implement WSC measures. These projects provide new business opportunities for different types of businesses that enable the transition, like designers, product suppliers and constructors. City administrations are becoming more and more aware for the need to create liveable and resilience cities by climate proof urban design not only in Europe but worldwide. This means that the market for these (new) businesses is expected to grow rapidly the coming years and a wealth of innovation which is likely to continue to drive future innovation in the urban climate adaptation market.

For example, the global green roof and green wall market is expected to grow to $ 7.7 billion in 2017 driven by mandates and incentives (Lux Research, 2012). Green roofs will account for $7 billion of the market, presenting a $2 billion opportunity to suppliers of polymeric materials such as geosynthetic fabrics and waterproof membranes. Green walls will grow to a $680 million market, needing for $200 million worth of materials such as self-supporting polyurethane foam growth media.

***Figure 3.5 Green roofs is a rapid growing market (Illustration: Lotte Fjendbo Møller Francis)***

Other examples of probable future needs are in designing, developing and constructing climate proof buildings and districts with multifunctional green spaces, infiltration systems, sustainable urban drainage, and rainwater harvesting systems. This will create large business opportunities. The following businesses have been identified, but this is probably not complete, that can benefit when enabling a WSC:

- Designers:
  - Architects and landscape architects
  - Landscape designers / gardeners

    - Consultancies and project developers

- Product supplier/manufacturers, for example:
    - Suppliers of green roofs and green walls
    - Suppliers of infiltration systems

- Constructors, for example:
    - Contractor of buildings and infrastructure
    - Sewerage undertakers
    - Drainage and landscape contractors
    - Gardeners

Two important boundary conditions for this growing market are: 1. **Innovation** should lead to increased cost-benefits of adaptation investments and 2. **Proof of concept** is required to create evidence base that these solutions are cost effective and create more benefits than traditional approaches.

In appendix I an overall overview is given of businesses, innovations or already market proven concepts, that contribute to Water Smart cities. This overview shows – however it is far from complete - that there is already a market for Water Smart solutions while the climate adaptation process in many cities is just about to start. The transition to water smart cities promises interesting business opportunities.

# 4. Barriers for WSC implementation

This section provides an overview and prioritization of barriers related to the implementation of water smart measures to realise the transition towards a WSC from the demand side perspective (often a public authority, 'the regime'; technology pull) as well as from the supply side perspective ((new) businesses, 'the niche'; technology push). As the regime operates according to their sanctioned discourse, which again is embedded in and controlled by the cognitive, normative and regulative conditions of the regime as illustrated in Figure 2.3 both the generation and uptake of new ideas depends on the specific configuration here. Based on literature review and output from the workshops held in Copenhagen (Denmark) and Amsterdam (the Netherlands) in November 2016, the following barriers are considered to be **main barriers** for establishing a solid business case on WS measures. With solid business cases public authorities and the business community are stimulated to invest in the transition from drained or sewered cities towards WSC, moving from bold ambitions towards actual initiatives, planning, realisation and maintenance of innovations. Appendix II gives a long list of barriers from literature.

## Barriers from demand side perspective

- **Time pressure (cognitive and normative)**: this contains two types of barriers, which are related to each other.
    - **Long term benefits versus short term investments:** The **costs are short-term planned but the benefits of WSC measures are long-term**. A WSC creates benefits that are the sum of many incremental actions and projects. This means that there can be a lag between investment in an individual project and the realisation of these benefits, particularly if the benefits relate to infrequent events such as floods or droughts. The challenge lies in framing today's expenditure as an investment in the future rather than as an inefficiency (Wong / CRCWSC 2014).

    - **Mismatch** due to the **long-term change** and uncertainty in the natural system, such as the increasing magnitude and frequency of extreme rainfall events, versus societal changes and **short-termism** in decision-making and policies. Often a public authority feels the **urge to act**, after a hazardous event, little time is taken to determine the best/ most sustainable measures, and **quick decisions are made** to react and prevent a possible upcoming event. This is also due to the current hydro-social contract many municipalities have with their citizens. Citizens are not aware of the long term developments concerning climate change and therefore not ask/demand from their municipality to react to these upcoming events (Li et al., 2016) (Biesbroek, 2014).

- **Regulations (regulatory)**: current regulations often only support conventional approaches, **businesses as usual**. They prevent or hinder the implementation of new and more integrated approaches and related measures for example the Dutch Building Degree (Bouwbesluit). New/ additional or more flexible regulations are needed that support the transition towards water smart cities (Workshop Amsterdam)

- **Uncertainties relating to climate change and lack of knowledge about effective climate adaptation strategies (cognitive)**: uncertainties in the exact timing and impact of climate change hinder the ability and the need of urge to make long-term decisions concerning implementation strategies towards WSC. In addition, there is a lack of knowledge about effective strategies and measures for climate adaptation (Biesbroek, 2014).

- **Lack of common vision, awareness and sense of urgency (cognitive)** within the public authority and by citizens hinders the process of setting up a long term strategy towards a water smart city (Biesbroek, 2014; Li et al., 2016; CS4B, 2015).

- **Lack of a clear problem-owner (normative):** there are many different stakeholders (public and private) responsible for different parts in the urban water system to create a sustainable and liveable city. It is unclear (conscious and unconsciously) who is main problem-owner and thus responsible to invest and implement strategies towards a WSC (Biesbroek 2014). A WSC is based on a systems approach rather than focusing on the optimal solution to a specific problem. **This foundation creates community-wide benefits; however, these can be difficult to describe, measure, and value, raising questions about who should pay** (Wong et al 2014)**.** Most conventional business cases are for set up for one company or organisation, with only direct costs and benefits identified and where possible valuated. For WSC business cases, multiple parties need to be involved to make a sound business case, thus taking into account the spatial aspects, direct and indirect costs and benefits to make the drivers for change more compelling

- **Integrated solutions in a sectoral world (normative):** The problem being solved is often based on the combined effects of multiple future scenarios for cities and towns, with associated uncertainty surrounding the impacts. If there is no agreement on the problems and opportunities, there can be no business case. **Barriers are the lack of knowledge and strong sectoral (financial) focus and instead of a more integral approach across sectors** (Li et al., 2016)**.**

## Barriers from supply side perspective

- **Unconvincing business proposition:** today's decision-making environment it is important to present a compelling proposition and a stakeholder alliance that supports this. Therefore it can be needed to **reframe the business proposal within a broader context,** to make the drivers for change more compelling, for example from climate issues to liveability and economy**.** And make the proposition relevant for different scales: local and system wide benefits (Wong et al., 2014).

- **Lack of documentation**: in order for a decision maker to be able to make a well-founded decision, documents are needed containing information about the performance, risks and costs of the measure. Often this information is lacking, because the measures are new and not yet applied in the field before or not long enough to give information about the exact performance-risks-costs.

- **Too small company for very large projects**: the implementation of a strategy towards water smart city consists often of a very large investment projects, for example the estimated budget the Cloudburst Management plan in Copenhagen is 3.8bn DK (resp. 500 MEUR) (The City of Copenhagen Cloudburst management plan, 2012). Large companies are often more in favour executing these projects as they have more experience and manpower, making them seemingly more reliable than small new companies (Workshop Copenhagen).

# 5. Roadmap towards Water Smart Cities

As stated before to realise a WSC a transition is needed with accompanying actions for different actors. Below a roadmap is defined, describing the different steps and actions needed from the different actors in this transition. This is a circular and iterative approach, where decisions and actions are continuously refined and adjusted (plan-do-act-check), in order to reach the WSC.

Municipalities need to have a leading role in this transition. They decide the goals and ambitions for their city, how these goals can be reached and realize projects. Although municipalities have a leading role in the transition, other actors (citizens, businesses, and research institutes) also play an important role (raising awareness & urgency, demanding functions, developing technologies, create evidence base, etc.). This roadmap is written where the municipality is taking the lead, but the possible actions or possibilities for other actors are inserted in the different steps.

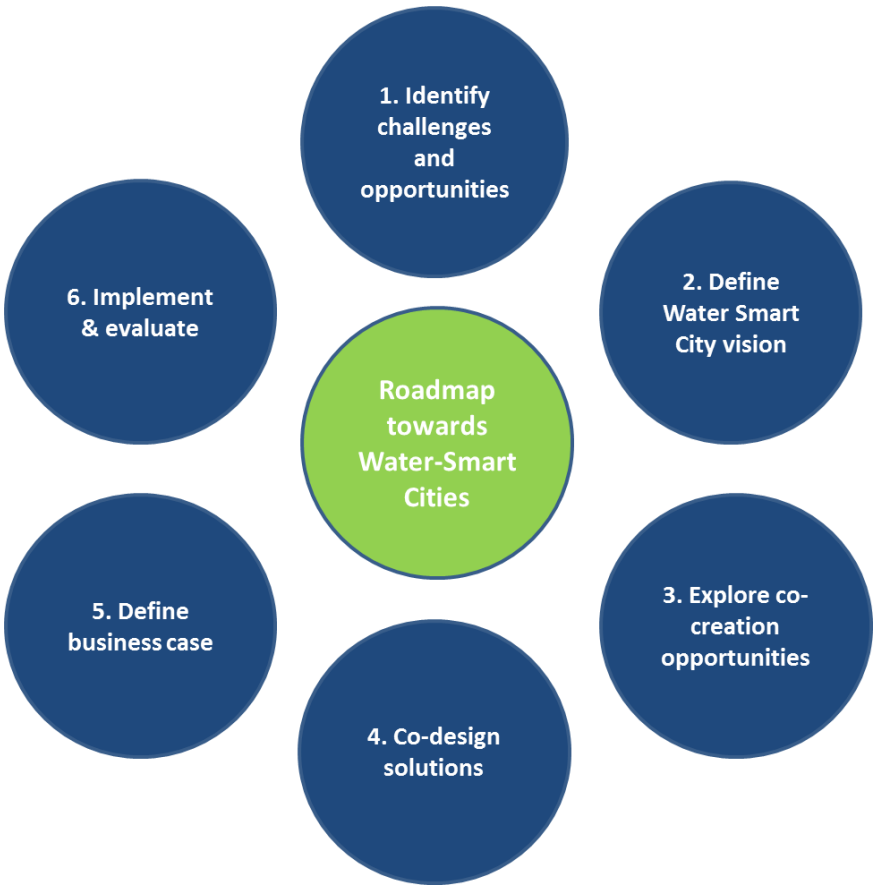



***Figure 5.1 Roadmap towards Water Smart Cities***

**Step 1: Identify the challenges and opportunities of the city**
At first the challenges and opportunities relative to the water system and the city liveability need to be known. These can be related to different ambitions and goals the city has, e.g. health, climate, energy, safety, poverty. From this analysis a new hydro-social contract between the city and the citizens and business can be defined. Citizens and companies can fasten or slow-down the transition, depending on their wishes, expectations and needs from their city. The Climate Atelier Approach can be a useful framework (figure 5.2) for creating climate-proof municipal spatial plans in four steps: 1) goal definition, 2) natural systems' analysis, 3) climate impact analysis, 4) interactive workshop – an atelier – designing a spatial vision for climate-proof development (Masselink et al., 2017).

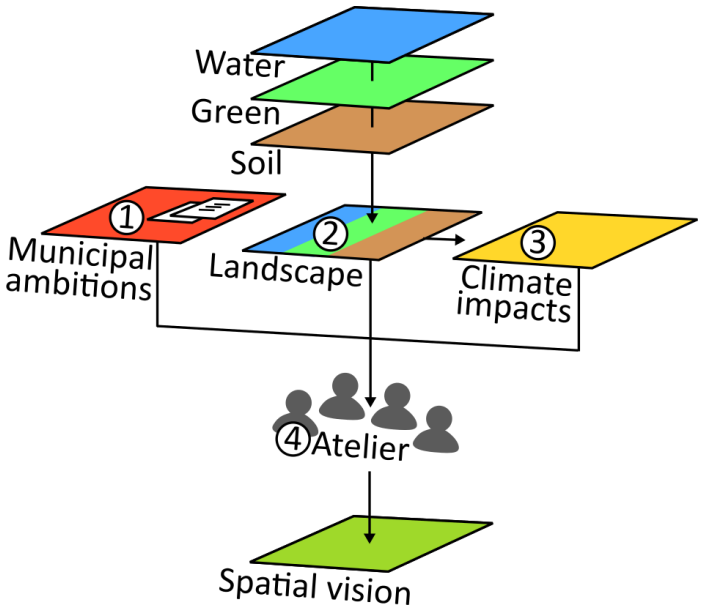



***Figure 5.2 The Climate Atelier Approach framework (Masselink et al., 2017)***

*Actions lead by the municipality and local water authority*:

1) Municipal spatial ambitions : Identify municipal spatial ambitions and planned developments. What goals, ambitions and challenges (e.g. health, liveability, energy, mobility and social issues) are important/ already formulated on city-district level. Is synergy possible with climate adaption goals? Are there possibilities to co-realize WSC ambitions with other ambitions?

2) Natural system analysis: Identify the physical and geographical context of the city. What functions and services can be employed from the natural system (soil-water-green) in order to reach societal goals and ambitions? And where are possible problems/challenges from the soil-water-green system?

3) Climate impact + vulnerability maps: What is the impact of climate change and where future problems occur in relation to expected urban growth and climate change scenario's related to the soil-water-green system and liveability; (storm) flood risks, risk for drought, urban heat maps and change in water quality and quantity. A stress test approach develops vulnerability maps for cities. Identify the overlap of hotspots for flood risk, drought, water quality and heat waves. It is also important to identify

the risks for vital infrastructure (e.g. energy supply, drinking water supply, accessibility to hospitals).

4) Climate Atelier: In a workshop/atelier, municipal experts design an integrated long term and integrated vision (2050 and beyond), providing guidance for climate considered spatial developments. This will result in a spatial adaptation vision.

*Main action from other actors is mainly to raise awareness and create a sense of urgency*:

- Research about effects and uncertainties concerning climate change (and other societal challenges);
- Citizens and companies notifying municipality of their needs and wishes and stress where these are not complied
- Media to create public awareness, exposing research results, point out where problems occur in society, reflect and form public opinion.

*Opportunities for business*:

- Consultancy and research: system analyses, problems and opportunities, tools and instruments for system analyses and vulnerability analyses.

**Step 2: A Water Smart City vision for your city**

A water smart city vision needs to be defined for the city. Each city has its own challenges and opportunities related to the natural system and liveability, thus there are different goals and ambitions for each city. Therefore each city needs to set up a vision "when are we a water smart city?" Key performance indicators need to be determined to assess the baseline and monitor whether goals are reached and where and what is needed to reach these? Switching between scales (from area to project, from current situation to future) is an important aspect.

*Actions lead by the municipality;*

1) Define WSC ambitions incl. key performance indicators: Define what a Water Smart City means for your city and set up a timeline with the short and long term vision. Identify Key Performance Indicators.

2) Synergy: What strategies and policies (e.g. health, liveability, energy, mobility and social issues) are already set to achieve these ambitions and overcome the challenges/problems for different scales (city-district)? How can WSC concept contribute to these ambitions?

3) Assess what is needed to reach WSC: Determine what is needed to reach the vision (based on KPI): type of projects, money, skills, pilots etc.

4) Stakeholder analyses: Who are the main stakeholders (positive and negative) in realising challenges and opportunities? Who are problem-owners and who is responsible? Built a team of advocates within and out of your organisation

*Action from other actors:*

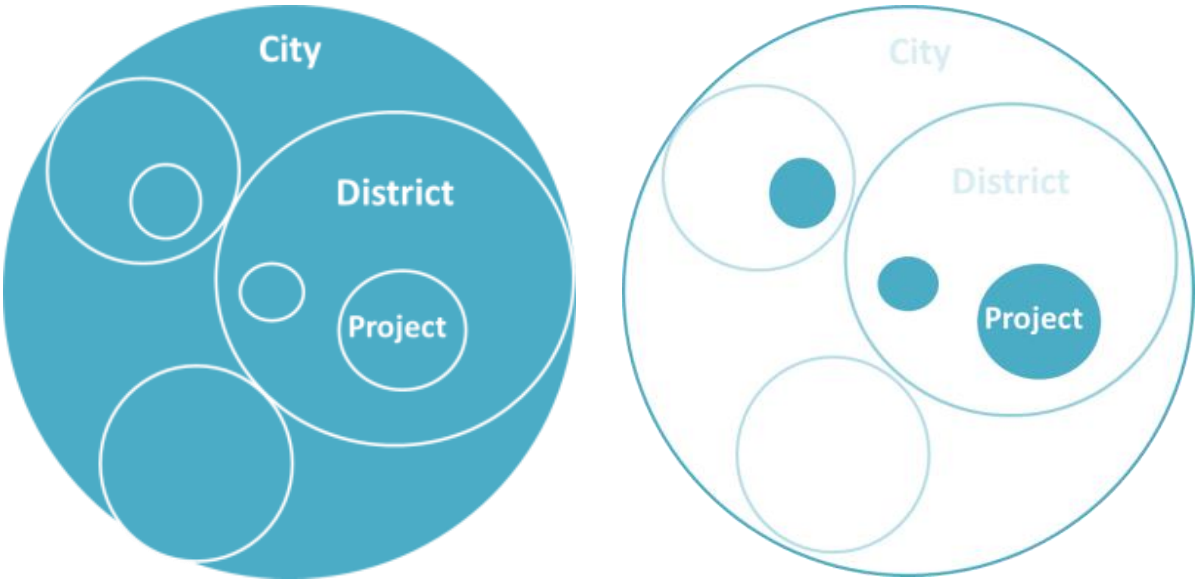
- Research: effects and effectiveness of measures, development of measures, monitoring, models;
- Citizens and business: wishes and needs concerning WSC, possibilities for co-creation options (likely with large companies)

*Opportunities for business:*

- Consultancy and research: Development of technologies and measures to enable the transition towards WSC (or frame to other set goals and ambitions) and know what their impact will be (relate to KPI's)

**Step 3: Explore co-creation opportunities**

In this step, we are going towards the implementation of WSC. Different pathways can be followed. Actions can be linked with already planned actions/projects, making small adjustments to a plan in order to make it more water smart, or a new trajectory is needed to be set up. Scale: district and project scale; short and long term timescale.




*Actions lead by the municipality:*

1) Co-creation possibilities: Visualize a map and timeline of already planned or future infrastructural projects and investigate co-creation possibilities by linking climate adaptation goals (the set KPI's) with planned infrastructural projects;

2) New trajectory: Where no co-creation is possible, because no projects are planned or because the needed change is too large to be obtained by co-creation, a new trajectory needs to be set up (incl. funding, skills, people etc).

*Action from other actors:*

- Research: effectiveness of measures, possible co-creation measures
- Business: co-creation possibilities with their land development
- Citizens: their role and possible contribution

*Chances for business:*

- Measures, products for possible co-creation and for a new trajectory to help reach the cities ambition.

**Step 4: Co-design solutions**

In this step the best (combination of) possible measures is analysed to determine the optimal way reaching ambitions and within the possible pathways (a specific project or a new trajectory). This can be best done integrated within the quatro-helix (government, citizens, business, and institutes; and with experts from different disciplines).

*Actions lead by the municipality:*

1) Identify possible effective measures: Depending on the natural system, the ambitions and location measures can have a different impact in reaching the set goals. Tools have been developed to help determine the effectiveness of measures, for example Adaptation Support Tool (AST, developed in Climate KIC) toolbox WSUD.

2) Co-design with stakeholders (niche-solutions): Design possible scenarios within workshops with different stakeholders and from different disciplines, to together create more value and find the most optimal solutions.

*Action from other actors:*

- Research: analyses of effectiveness of measures, development of instruments/tools; contribute to co-design workshops concerning soil-water system, impact of measures etc.
- Citizens and business: contribute to the workshops concerning needs and wishes.

*Opportunities for business:*

- Development of technologies and measures;
- Design strategies for public space, making them more WSC
- Advice and consultancy.

### Step 5: Define solid business case

The municipality is responsible for maintaining and managing essential functions for the public, such as ensuring dry feet and a save, clean, healthy and pleasant environment. These functions can be obtained both by deploying anthropogenic or natural assets. Consideration of the long term performance, risks, costs and benefits can support choices in how to provide specific functions: with natural solutions, civil engineering or a mix.

From the proposed combination of possible measures (scenarios), the best (most optimal) business model should be chosen. Each scenario has its benefits and disadvantages in order of performance (incl. flexibility), costs and value, and risks over a certain timespan. All these factors should be balanced with each other to determine the most optimal business model, which will be converted into a project plan. A a solid business case exists of the following components:

1) Problem & Solution: Identify the problem, possible solutions and co-creation opportunities. Cities/regions have their own ambitions and challenges. By communicating how the project fits within a larger context, linking to external drivers and creating co-benefits, will support implementation.

2) Valuing Costs & Benefits: This is a fundamental part of the business case, as decisions for approval or rejection are cost-benefit based. For WSC measures, besides monetary valuation also the intangible value must be taken into account. Many of the benefits of a WSC measure are long term, in contrast that most costs are short-term. Therefore the business case needs to address the question of who pays or takes the risk for these long-term benefits.

3) Stakeholder: For a sound business strategy it is necessary to know who your stakeholders are, your partners and possible "enemies". Built team of advocates.

*4)* Actions: Define actions to be taken by who for implementing WSC approach

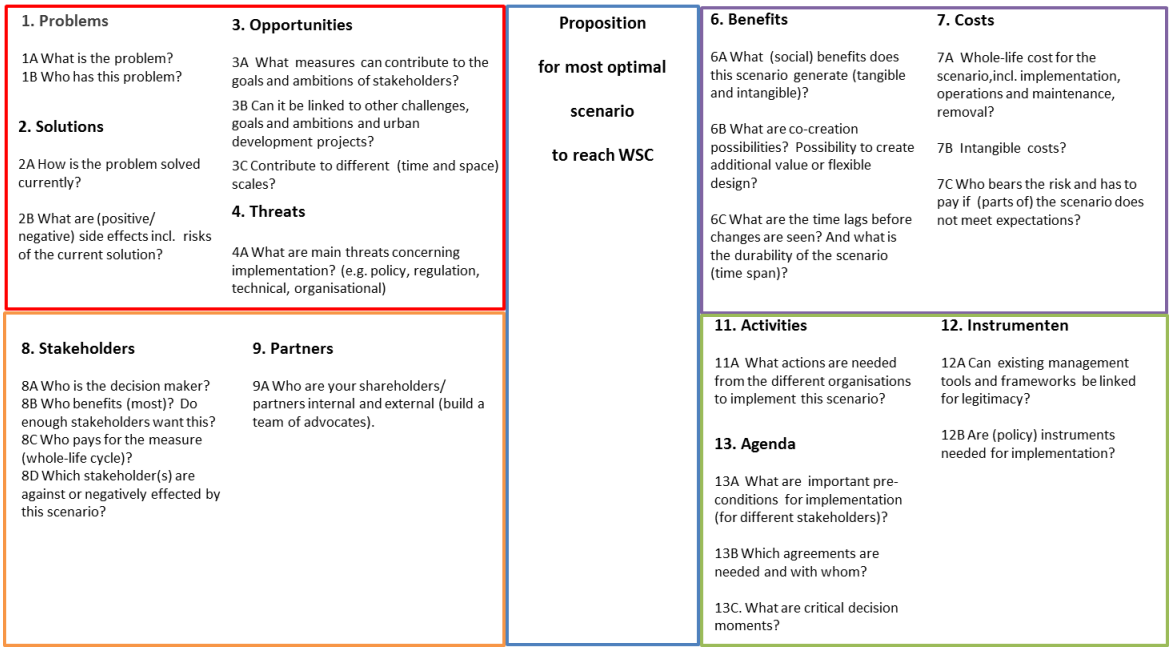



***Figure 5.3. Implementation business canvas model***

**Step 6: Implement & evaluate**
(Continuous) implementation of WSC measures, celebrate and learn from them and where needed adjust the process or ambitions until it is business as usual (plan-do-check-act). By pilots (set up from scratch), living labs (in real areas), small scale or large scale project, co-creation or new trajectory. Important to learn from the projects, proof of concept, and to know if the ambitions are met, therefore monitoring and proper data management and analysis is very important. Continuously improving the evidence base is required.

*Other Actors:*

- Research: monitoring, living labs, improve measures, collect and analyse data

*Opportunities for business:*

- Construction, design, technologies/measures, consultancy

# 6. Case studies

## The Netherlands - Amsterdam

**Dutch climate challenges**
The Netherlands is extremely vulnerable for climate change. One third of the Netherlands is below sea level. Sea level rise will increase the coastal flood risk. The Netherlands is heavily urbanised. Urban areas are already dealing with heavy rains and heat waves and climate change will increase the risks for urban floods and heat. In the Dutch Delta programme a long term strategy for climate adaptation is developed together with all important stakeholders (governments, businesses, research institutes, ngo's) to ensure flood protection, fresh water supply and urban climate resilience for 2100. In 2014 the Dutch cabinet agreed with a long term action plan and ensured a long term financial contribution for climate adaptation actions.

The sense of urgency for climate adaptation in The Netherlands is growing. It is raining harder and more intensely. Recent urban floods, periods of droughts and heat waves help to create awareness. In 2014 some heavy rains (> 100 mm) caused major damage in cities like Amsterdam and Arnhem. In 2016 some heavy rains during storm events caused over € 500 million damage in the south eastern part of the Netherlands.

**Amsterdam Rainproof (www.rainproof.nl)**

Amsterdam developed a strategy to cope with heavy rains: Amsterdam Rainproof. Amsterdam is simply not equipped to handle all that water. Amsterdam is – just like other cities – filled with buildings and pavements, the rainwater has nowhere to go. This results in flooding and extensive damage to houses, shops and offices. The public sewer system has to process more and more water. But to just keep on increasing its capacity isn't the solution. Amsterdam is looking further than underground drainage systems and started designing smarter outdoor urban spaces where we can retain and store the rainwater where it falls. Amsterdam Rainproof aims to create awareness and make Amsterdam rainproof for rain events up to 60 mm. Amsterdam is considered rainproof when a rain event of 60 mm does not lead to damage and with more extreme rain events the negative effects on the most vital infrastructure (high ways, public transport) and vulnerable objects (like hospitals, energy supply, drink water supply) is minimized.

The network of Amsterdam Rainproof wants to activate, connect, and stimulate citizens, city builders, officials, entrepreneurs and housing corporations to make the city more rainproof. The strategy is to build and create an influential, broad, sustainable Rainproof platform of people and organisations. Rainproof puts the issue on the agenda of politicians and residents. Rainproof measures are needed from all stakeholders, from greening private gardens and public space, reuse of rain water and create value. Amsterdam aims – where possible - to combine rainproof measures with already planned developments. Together a more resilient city for dealing with extreme rainfall is created. Amsterdam Rainproof works with groups that can make a difference; it connects to closely related initiatives and current projects to achieve a quick and embedded result; focus on frontrunners and ambassadors; and facilitate the program instead of implement it by themselves. The slogan of Amsterdam Rainproof: Every drop counts.

**Living Lab Green Street**

With a mixed group of > 35 participants from governments, businesses, NGO's and research institutes this Climate KIC pathfinder project organised a workshop (November 30st 2016, Amsterdam) to discuss ideas and opportunities for a living lab green street in and around Amsterdam.

The Living Lab Green Street is a demonstration project to test and show innovative solutions for climate resilience, circularity and smart cities on street level. The pressure in urban areas increases by demographic and climate change. To deal with this strategies are needed on how to design smart and healthy cities. One of these strategies is the development of Green Streets in European cities, the streets of the future. As streets is the smallest building block in city planning, especially for urban services like energy, drinking and waste water and storm water drainage. The chances are here!

When (re)designing a street, with the Green Street concept, one should look broader than one challenge / goal and function. Streets contain the most complex and costly parts of the infrastructure: the last mile. Streets are therefore one of the most challenging elements for developing and testing new concepts. Besides climate adaptation, it also offers opportunities to increase the liveability, and enhance a greener and circular city. To realise these green streets, new solutions, approaches and technologies are needed, making it a good opportunity for companies to test and implement their new solutions and technologies (leading edge technologies). Monitoring performance of measures (for flood protection, urban heat, circular economy etc.) in green streets living labs to create an evidence base is considered as an important boundary condition. A green street requires close collaboration between governments, businesses, researchers, NGOs and local citizens.

***Figure 6.1 Visualisation of the Living Lab Green Street***

In the workshop we explored ideas for the Green Street concept, created enthusiasm and identified stakeholders and consortia for realisation of this initiative in Amsterdam, Almere and other cities in the Netherlands. This initiative will create awareness and evidence base to show that climate adaptation is an opportunity to improve the liveability of the city and at the same time is an interesting and solid business case. Ideas/ opportunities for Living Labs Green Street (explored in the workshop)

- Implement and test performance of nature based solutions for climate resilience by reducing flood risk and urban heat waves (green roofs, green walls, rain gardens, bioswales, urban forestry, tree nursery, etc.)
- Larger communal gardens and smaller private gardens
- Closing the urban water cycle
    - Reduce water demand and improve water use efficiency
    - Rainwater harvesting and reuse
    - Decentral waste water treatment and reuse of waste water for irrigation
- Recovery of nutrients, water, carbon, energy
- Increase self-sufficiency for water, food, energy
- (Vertical) urban farming
- Experiments with green measures (plants, trees, green walls) improving air quality
- Multiple use of space such as making roof space accessible, reduce parking space for green / play grounds / water storage
- Local energy production by solar, wind, disconnect from gas pipe-lines
- Smart grids, off grids
- Mobility – incorporate more electric charging possibilities in the street, completely remove cars, support cycling over cars

Involved stakeholders have shown interest to invest in Living Lab Green Street. Municipalities / water authorities are willing to provide experimentation space and identify promising future approaches/ business cases, businesses are interested to test and showcase their products/innovations and researchers are interested to integrate urban innovations and monitor performance (data platform) in order to create an evidence base for the best future approaches to create liveable, resilient and circular cities.

In the workshop the most important barriers for climate adaptation innovation were identified which are relevant for Living Lab Green Street:

- EU and national policy and regulation is a major obstacle for innovation and integrated approaches;
- City is planned and managed sectoral where each department has his own targets and goals;
- Sectoral financial structures hinder integrated approaches;
- Investment cost for climate adaptation are high with a long term return on investment;
- Sense of urgency for climate mitigation and adaptation is missing by citizens and city council;
- There is uncertainty about the cost-effectiveness of climate adaption measures.

In 2017 next steps will be explored to realise comparable Green Street living labs in The Netherlands and throughout Europe.

## Denmark - Copenhagen

### Danish climate challenges

The major challenges for Denmark for adapting to climate changes are related to increased risk of pluvial flooding and storm surges. This is especially the case for urbanized areas, where the drainage capacity of the sewer systems is unable to cope with the new intensities and durations of precipitation events, and for cities located along the long Danish coastline. The climate change predictions for Denmark points to a 30 % increase in annual precipitation towards the end of the century, more extreme rain events especially in the summer period, and a higher frequency of storm surges, however much dependent on the specific neighbouring ocean. Denmark has plentiful and good quality groundwater aquifers and with an expectation of more, rather than less, annual precipitation the concern for water supply is negligible, although some concern about intruding saltwater in response to rising sea level has been expressed.

The awareness of need for climate change adaptation is outspoken. In 2008 the Danish government stated that the responsibility for climate adaptation lies with the municipalities, and by January 2015 all municipalities were obliged to present a climate adaptation plan, describing to what extent climate adaptation is needed. Alongside the development of these plans a number of research and innovation projects on how to adapt to a changing climate have been carried out, and concurrently a number of networks for sharing of ideas and findings have evolved. The forerunner in Denmark is the capital represented by its two municipalities, Copenhagen and Frederiksberg, as well as the two other major cities in Denmark, Århus and Odense. But also a number of other cities present a progressive approach to climate change adaptation, e.g. Gladsaxe, Middelfart and Vejle. Many of the projects are described here: www.larindenmark.dk.

### Copenhagen climate adaptation plans

The two municipalities within the boundary of  the city of Copenhagen have developed individual, but fully coordinated and aligned plans for adaptation to the future climate conditions. Frederiksberg Municipality is completely surrounded by Copenhagen Municipality, and share both water supply and waste- and stormwater management systems with Copenhagen Municipality. The city of Copenhagen is combined sewered for more than 90 % of the area and all stormwater runoff from both municipalities goes to one of two treatment plants. Copenhagen Municipality imports practically all water from well-fields in municipalities located some 50 to 100 km from the city limit. For Frederiksberg Municipality this is the case for 2/3 of the water, while still 1/3 is abstracted from within the municipal border limit.

In 2011 Copenhagen Municipality published its first plan on how to respond to climate changes (http://en.klimatilpasning.dk/media/568851/copenhagen_adaption_plan.pdf). It was entitled Copenhagen Climate Adaptation Plan and it contains a goal of zero carbon emission by 2025, a goal of extra 30 % capacity in the sewer system by the year 2111 by means of disconnections preferably to blue-green solutions in the urban landscape, otherwise by conventional sewer separation, and finally a more lose goal of mitigating urban heat island. In response to a large cloudburst on July 2 that same year that flooded significant parts of the city, an extra plan was required by the mayor of the city, to cope better with such situations in the future. This resulted in the Copenhagen

Cloudburst Management Plan (http://en.klimatilpasning.dk/media/665626/cph_-_cloudburst_management_plan.pdf) published in 2012, in which an extra service level for the drainage capacity of the city is promised. In addition to the ordinary goal of no water on terrain more frequently than once in 10 years the city now also promises the citizens that no more frequently than once in 100 years cloudburst ponding levels will exceed 10 cm, except for areas designated for flooding.

In 2012 the Frederiksberg Municipality published their cloudburst plan, which contains the same goals for adaptation to more precipitation, both the 10 year and the 100 year service levels, and reduction of urban heat island. The plan further states that the investment in climate adaptation must as far as possible seek to support the overall urban development plan as described in the Frederiksberg Strategy.

The cloudburst plan is shared 100 % between the two municipalities. The cloudburst plan is based on detention and discharge of runoff volumes exceeding the 10 year event by using the streets as transport vectors. 60 cloudburst routes referred to as cloudburst branches have been pointed out to drain flood water from potential blue spots to the ocean, a river or a city lake. To realize the cloudburst branches some 350 projects have been decided, each involving one or more streets, plazas or other open spaces to be re-profiled for flood water transport. To bypass local terrain peaks underground pipes will be used. For more serious barriers like low lying railways, the metro and utility pipes four new underground tunnel pipes are under construction. Some of the 350 projects are planned to be in the form of green streets where all stormwater runoff is supposed to be managed without making use of the sewer system, i.e. a full disconnection.

**Workshop on barriers and paths forward**

With the objective of mapping the perspectives among key actors in Copenhagen on the different approaches to climate adaptation we conducted a workshop with 10 invited professionals from municipalities, private companies and a philanthropic environmental organization. The workshop aimed to answer the following specific questions:

- To what extent is distributed detention-retention (DDR) systems, also known as SUDS or landscape based stormwater management solutions, an adequate response to
    - Maintain the current 10-year service level of Copenhagen drainage systems, despite the expected 30 % increase in intensity and duration of storm events in the future relation solutions based approach able?
    - Ensure the Copenhagen 100-year service level of no more than 10 cm of ponding water except for areas designated for flooding?
    - Reduce the urban heat island effect?
    - Adapt cities to other climate change related challenges?
- Are DDR-solutions able to honor the vision of creating value to the city in addition to the mere stormwater management?
- Can climate adaptation become more sustainable and innovative? What are the major barriers and shortcomings and which pathways are considered promising?

The workshop participants are listed in Table 1. As seen from Table 2 the workshop program consisted of presentations by researchers followed by questionnaires to be filled in individually and plenary discussions.

***Table 6.1: Overview of workshop participants. The ten listed first were those invited by the authors listed last.***

| | # | Affiliation | Type | DDR-role |
|---|---|---|---|---|
| Morten | 1 | Copenhagen Municipality | Public partner, or 'end user' | Officer on environmental issues |
| Jeppe | 2 | Copenhagen Municipality | Public partner, or 'end user' | Officer on project coordination |
| Dorthe | 3 | Frederiksberg Municipality | Public partner, or 'end user' | Officer on project development and implementation |
| Claus | 4 | Gladsaxe Municipality | Public partner, or 'end user' | Officer on environmental issues and project development |
| Trine | 5 | Rambøll | Private engineering consultancy | Consultant in flood mapping by use of GIS; Involved in network among young water professionals |
| Niels | 6 | Niels Lützens Tegnestue | Private landscape architect consultancy | Consultant in design and public/resident involvement; Signing contracts |
| Felix | 7 | Niels Lützens Tegnestue | Private landscape architect consultancy | Create contacts and business opportunities in China |
| Marie | 8 | Thing og Brandt | Private landscape architect consultancy | Consultant in design and public/resident involvement; Signing contracts |
| Louise | 9 | Grassov og Schultze | Private landscape architect consultancy | Consultant in design and public/resident involvement; Signing contracts |
| Anders | 10 | Miljøpunkt Nørrebro | Philantropic association working for improved local environment and climate resilience | Facilitating local initiatives and discussions with Copenhagen Municipality |
| Marina | 11 | University of Copenhagen | Knowledge institution | Research focus: stormwater quality control; innovation of dense city DDR-elements; knowledge sharing |
| Li | 12 | University of Copenhagen | Knowledge institution | Research focus: urban planning, resilience and sustainable freshwater management; stakeholder mindset change… |
| Ole | 13 | University of Copenhagen | Knowledge institution | Research focus: urban planning and green infrastructure development; upscaling… |
| Dorthe | 14 | University of Copenhagen | Knowledge institution | Research focus: innovation and networking… |

***Table 6.2: Overview of workshop content***

| Section | Title of oral presentation | Individual questionnaire | Discussion target |
|---|---|---|---|
| 1 | DDR-based climate adaptation – how large is the potential? | Does DDR hold the answer to climate adaptation? | Assessment of DDR-potential, and reasoning behind |
| 2 | Sustainability and innovation in climate adaptation in Copenhagen and Beijing | Which added values related to DDR do you focus on? | Examples of realized added values and suggestions on how to increase added value |
| 3 | Methods and ideas on how to strengthen innovative collaboration among municipalities, water utilities, private companies and knowledge institutions | How can sustainibility and innovation be fortified in todays' practices? | List of experienced challenges and suggestions on ways forward |

The workshop provided an instant measure of the Danish situation regarding the listed questions, and pointed to a need for clarification of terms, as well as an aspiration for a new kind of network and collaboration among actors. This network should go beyond ordinary networks by targeting inter-disciplinary innovation, high-speed sharing of challenges and breakthroughs, and accept a network maturing path that allows for spiraling and meandering in activities and partners. Ideas on how these needs can be met are elaborated upon in the discussion part.

According to workshop participants the DDR-solutions can constitute stand-alone solutions for reaching the goal of 30 % more space in the combined sewer system of Copenhagen by means of disconnections of surfaces that today discharge to the sewer, while regarding the 100 year event service level of a maximum flood depth of 10 cm there is consensus that DDR solutions cannot be stand alone. Either such solution must be combined with grey solutions like the cloudburst branches, or controlled flooding of areas otherwise not reserved for flooding must be adopted. The workshop points to a number of added benefits related to DDR-solutions that the professional participants consider real and important including both physical improvements of the urban environments to the benefit of inhabitants and biodiversity as well as soft skills related to collaboration. Finally it was possible, based on the input from the workshop, to outline some parameters that seem to be of importance if professional networks are to enhance the sustainability dimensions of climate adaptation, relating to visions creation, knowledge sharing, and network adaptation to societal development.

# 7. Lessons learned

- **Climate adaptation is a huge opportunity to improve the quality of urban life:** Adaptation creates opportunities to develop more sustainable and liveable cities. It should be seen as an opportunity, rather than a problem that may lead to additional costs. Cities should shift the perspective from risk to an opportunity to create value for citizens and make the city more attractive, resilient and economically sound.

- **Redesigning cities from drained cities to Water Smart Cities will become more important in the near future:** Water plays an important role for the liveability of cities. Many cities deal with increasing risks for water shortage, floods and heat waves. These challenges ask for a systemic approach and a transition in urban planning and urban water management. We have to rethink the way we deal with water in our cities and we need to (re)design cities moving from drained cities to green, resilient and circular cities. Collaboration between businesses, public authorities, researchers and citizens plays a unique part to ensure rapid transition. A smart combination of technical, civil engineering and nature based solutions will result in Water Smart Cities.

- **Increase awareness and involve all stakeholders**: It is important to engage the quatro-helix - citizens, businesses, local governments and researchers- in order to create awareness, stimulate stakeholders to take their own responsibility and co-create local solutions. Developing joint visions of urban futures and how to deal with climate challenges and create synergy with other goals can connect long-term challenges to short term urban planning.

- **Urban (re)development programmes offer large opportunities for co-creation:** Cities need sound business cases for urban adaptation. In many cases it will cost less to incorporate adaptation in the process of renewing, maintaining and expanding urban infrastructure. Any (re)development programme (such as renewing sewer systems, refurbishment of houses) should consider creating synergy with climate adaptation goals. Infrastructural developments will often have a planning horizon of 30-50 years or longer. The impact of climate change on a long term time scale should be considered.

- **Climate adaptation will create large business opportunities:** Redesigning cities from drained cities towards Water Smart Cities creates business opportunities. There are already many businesses available and this market and the need for new innovative water smart solutions is growing. The transition towards Water Smart Cities will boost innovation opportunities.

- **There is a need for evidence base and knowledge transfer of climate adaptation strategies:** There is a strong need for showcases and best practises about cost-effective climate adaptation strategies and experimentation space for co-creating new solutions. Cities need this knowledge for upscaling in order to become climate adaptive. Investing in living labs or demonstration projects where governments, citizens, researchers and businesses test and monitor innovative and nature based adaptation approaches is important.

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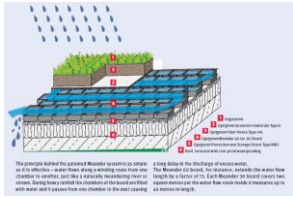
# Appendix I Overview of WSC innovations

| Goal | Company<br><br>Website | Product/service | Scale | Type | Innovation Phase | Photo |
|---|---|---|---|---|---|---|
| Reduce water use / Improve water efficiency | Duravit<br><br>www.duravit.nl | Durastyle Dry, a waterless toilet for water use reduction in houses and buildings | Building | Technical solutions | Commercial product |  |
| | Upfall shower systems<br><br>www.upfallshower.com | Upfall Shower "the new showers" Enjoy 40 liters of water per minute and consumption only 1.5 liters with the most economical, powerful and durable shower in the world!<br>Save up to 90% on water and energy ($CO_2$). | Building | Engineering Solutions | Commercial product |  |
| | Hydrao, smart shower for smart savings.<br><br>www.hydrao.fr | HYDRAO First lights up the water spray with different colors depending on the amount of water used. Powered by the shower's natural water-flow, no external power supply is needed. It therefore allows you to instantly control you water consumption and the energy needed to heat it. | Building | Technical solutions | Commercial product |  |
| | Grohe<br><br>www.grohe.nl | Water saving showers heads | Buidling | Technical solutions | Commercial product |  |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Hamwells<br><br>www.hamwells.com | E-shower with a classic mode to provide low flow or a circulation more to adapt Rapid Refreshment technology that filters, replaces and purifies water. With this mode, each water drop can be used 7 times, to save up 80% on energy and 90% on water. | Building | Technical Solutions | Commercial product (Climate KIC) |  |
| | GEP regenwater<br><br>www.regenwater.com | Rainwater tanks and systems. Our designs and products provide total solutions for environmentally responsible decentralized water management. GEP is developing and supplying systems for decentralized water management to improve the quality of water, use the water and prevent flooding. Thus, GEP will make uncoupling and use of rainwater for everyone possible. | Building / District | Engineering Solutions | Commercial product |  |
| | HB Watertechnologie<br><br>www.hbwt.nl | The water technical activities include irrigation systems and irrigation systems for roof gardens, vertical gardens, indoor gardens, planters and other high-quality green projects. Also provide water treatment, water filtration systems and other technical solutions for water features. | Building | Nature Based | Commercial product |  |
| | Wavin<br><br>www.wavin.nl | Wavin offers customized solutions for improving drinking water use efficiency in buildings. | Building | Technical solutions | Commercial product |  |

| Goal | Company<br><br>Website | Product/service | Scale | Type | Innovation Phase | Photo |
|---|---|---|---|---|---|---|
| Retention / Infiltration / Water storage | Optigreen<br><br>http://www.optigreen.co.uk | Systemic solutions for green roof systems. The Optigreen Retention Roof, using the Meander 30 board, reduces the burden on the drainage system during intense rainfall* by 99 %. | Building | Nature based and technical solutions | Commercial product |  |
| | Polderdak<br><br>www.polderdak.nl | A smart solution to retain, store and drain large amounts of rain water on green rooftops. | Building | Nature based and technical solutions | Commercial product |  |
| | Sempergreen<br><br>www.sempergreen.com | Sempergreen is market leader in direct-green solutions for your green roof, living wall or ground cover. | Building | Nature based and technical solutions | Commercial product |  |
| | Mobilane<br><br>www.mobilane.co.uk | Even where green is not self-evident, for example because of lack of space, the applications of the innovative green systems of Mobilane offering new possibilities for living green: Mobiroof (green roof) and Wall planter (green wall). | Building | Nature based and technical solutions | Commercial product |  |

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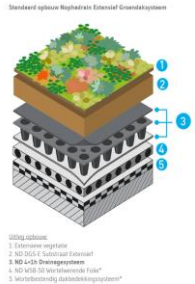
|---|---|---|---|---|---|---|
| | Nophadrain<br><br>www.nophadrain.nl | Nophadrain smart green roof systems: Green roofs to relieve sewer and provide cooling. | Building | Nature Based and technical solutions | Commercial product |  |
| | Groene Water Wand<br><br>www.groenewaterwand.nl | The 'Groene Water Wand' combines water storage, green wall and property boundary | Buidling | Nature Based Solutions and technical solutions | Proof of concept | |
| | Rainwinner<br><br>www.rainwinner.nl | The Rainwinner® is the state of the art solution when it comes to 'grip (rain) water. Functional garden element and water supplier in one. The ideal solution for large-scale storage of rainwater that takes up very little space and thus ideally suited for urban areas. | Building | Technical solution | Commercial product |  |
| | Aquabase<br><br>www.aquabase.info | A foundation with hollow space, strength and stability to buffer water in the public space. It can be used under a surfacing (paving or asphalt).In creating a stable cavity AquaBase has a huge advantage. Thanks Accorder® TenCate improve the stability creating more capacity in the construction. | District | Engineering solution | Commercial product |  |
| | Aquaflow<br><br>www.aquaflow.nl | The water storage path: Water storage under roads to buffer rainwater from roofs and streets and to purify | District | Engineering Solutions | Commercial product |  |

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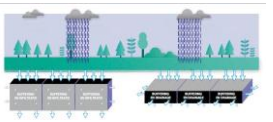
|---|---|---|---|---|---|---|
| | Drainvast bv<br><br>www.drainvast.nl | Drainvoeg, a simple and effective solution to allow rainwater to infiltrate through the joints into the soil and new paving material. Drainstop has developed a vortex that only works at a certain maximum water level in the water buffering foundation. So only in case of extreme precipitation. DrainBrick : a well in stone format. At the desired location is removed a stone from the paving and replaced by a drain brick. The water flows through the drain in the brick substrate. | District | Engineering Solutions | Commercial product |  |
| | Rain(a)way<br><br>www.rainaway.nl | Rain (a) Way creates Urban infiltration, so the natural cycle of rain water is retained in the urban area. By Rain (a) Way We pay much attention to material, shape, structure and details in design and design of products and places. | District | Engineering solution | Commercial product |  |
| | Micro Urban Wetlands<br><br>www.fieldfactors.com | Micro Urban Wetlands: Integrating ecosystem services in urban areas. Micro Urban Wetlands is a design research into small-scale applications of nature-based solutions for urban water management. The project focusses on the design of integral solutions and learning from practical experiments. | District | Nature based solutions | Proof of concept | |
| | Drainproducts<br><br>www.drainproducts.nl | Drainproducts developed several products for rainwater infiltration and drainage: Permavoid, Flowblock, Codrain, Stabidrain. | District | Engineering Solutions | Commercial product |  |
| | Hydroblob<br><br>www.hydroblob.com | Hydroblob® is a new type of rainwater buffer. It collects and stores excessive rain and groundwater, as well as normal rainwater (through a connection to your drainage system). | Building /District | Engineering Solution | Commercial product |  |
| | Hydrorock International<br><br>www.hydrorock.nl | Hydrorock® is the result of a collaboration between two companies in the insulating substrates and rockwool industry: Rockwool and Asbipro group. Hydrorock focuses on developing, manufacturing and marketing of innovative products in field of rainwater and surface water. A | Building / District | Engineering Solutions | Commercial product |  |

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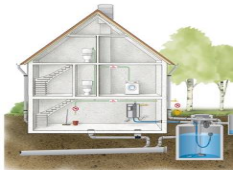
|---|---|---|---|---|---|---|
| | | range of solutions for disconnecting rainwater, water storage, drainage, infiltration and irrigation using mineral wool as the base material. There are also solutions specially prepared padding that hold either moisture or promote infiltration. | | | | |
| | NeringBodel<br><br>www.neringbogel.eu/ | Due to the underground installation of tunnel elements storage and / or infiltration of rainwater is possible in a wide range of applications, ranging from detached houses to large building complexes, the construction of streets and districts to business - and industrial sites | Building / District | Engineering Solutions | Commercial product | |
| | Wavin<br><br>www.wavin.nl | Intesio concept of Wavin offers customized solutions for the sustainable discharging, temporary storage, infiltration, purification and reuse of rainwater. | Building | Engineering Solutions | Commercial product |  |
| | O2dit<br><br>www.dsi-infiltratie.nl | Dusen Saug Infiltration: innovative technology in the construction of drainage or return the realization of a highly efficient rainwater infiltration system. The favourable effect is based on the determination of the correct point of infiltration and causing in the right way the required wave-like movement (momentum). | Building / District | Engineering Solutions | Commercial product |  |
| | GEP regenwater<br><br>www.regenwater.com | Rainwater systems. Our designs and products provide total solutions for environmentally responsible decentralized water management. GEP is developing and supplying systems for decentralized water management to improve the quality of water, use the water and prevent flooding. Thus, GEP will make uncoupling and use of rainwater for everyone possible. | Building / District | Engineering Solutions | Commercial product |  |
| | MultiBouwSystemen<br><br>www.mbswaterberging.nl | Water storage cellars from precast concrete provides structural and sustainable solutions in the field of water storage to prevent flooding during extreme rainfall. For example beneath squares and parking lots, collecting rainwater which then slowly flows back into the soil or delayed discharged to the municipal rainwater drains or surface water. Also, the rain water can be retained for reuse. | District | Engineering Solutions | Commercial product |  |

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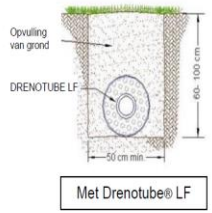
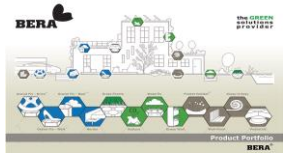
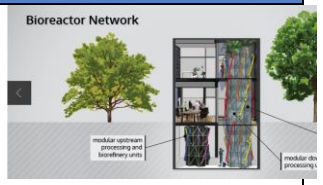
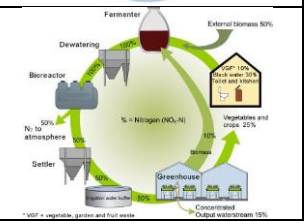
|---|---|---|---|---|---|---|
| | HTD<br><br>www.hatekgroep.nl | Drenotube is a drainage and infiltration system, suitable for infiltration and drainage. | District | Engineering Solutions | Commercial product |  <br>Met Drenotube® LF |
| | Bleijko<br><br>www.bleijko.com | Permeable and water passing pavement (concrete) in combination with our special foundation system ensures efficient handling of rainwater | District | Engineering Solutions | Commercial product |  |
| | TFI Vitaler Groen<br><br>www.tfi-international.com | The TFI method mimics a real forest situation at any place in the Netherlands, even in urban areas. No use of heavy machinery or drastic actions, but fit natural soil conditioners via a short, effective therapy. | Building / District | Nature Based Solutions | Commercial product |  |
| | Tree Ground Solutions<br><br>www.tgs.nl | Tree Ground Solutions for the "modern habitat 'for trees and offers solutions for the full establishment of habitats in and around the urban area. With our systems we regulate water, food and oxygen supply; the basic elements for a healthy growth of trees. | District / City | Nature Based Solutions | Commercial product |  |
| | Intercodam<br><br>www.intercodaminfra.com | RoofDrain drainage mats provide buffering and rapid drainage of excess rainwater, in all types of green roofs. Other systems are RoofDeck and Deckdrain | Building / District | Engineering Solutions | Commercial product | |
| | Bera<br><br>www.bera-bv.com | The green solutions provider, innovative solutions for rainwater storage and infiltration. Underground buffering or modular vegetation for green roofs provide reduction in storm water runoff and improve biodiversity in urban areas. | Building | Engineering Solutions | Commercial product |  |
| | ModuTank<br><br>http://www.climate-kic.org/start- | Water conservation and water supply management. A scalable and modular composition of standardized panels that can be set up quickly to form water tanks of various heights and | Building / District | Engineering Solutions | Climate KIC start-up; not founded yet | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | ups/modutank | diameters. | | | | |
| | Disdro<br><br>www.disdro.com | Real time control of the entire system. Maintenance free rain gauges (sensors) that can measure rainfall cheaply and accurately, providing real-time and cost-effective rain data. | District / City | Technical Solutions | Commercial product (Climate KIC start-up) |  |
| | Mobile Water Management<br><br>www.mobilewatermanagement.com | Real time control of the entire system. MWM provides multiple trackers to measure water level, quality variable, discharge and flow etc, by using smartphones to take a photo of the water. The pictures are geo-tagged and data can be exported to Water Information Systems. | City | Technical Solutions | Commercial product (Climate KIC start-up) |  |
| | | | | | | |

| Goal | Company<br><br>Website | Product/service | Scale | Type | Innovation Phase | Photo |
|---|---|---|---|---|---|---|
| Water treatment / water reuse | | Water efficiency, water treatment. Waterhub, a modular and integrated infrastructure service that can cater to the needs of the urban slum communities such as sanitation, wastewater treatment, energy generation, food production etc. The aim is to tackle with problems arose by urbanisation, global warming and water crises | Building / District | Technical Solutions | Commercial product (Climate KIC start-up) |  |
| | Global Wetlands<br><br>http://www.wetlantec.com | Wetlantec builds natural water treatment. We stand for improvement at the local level in the use of our waste, - drinking water and surface water. We believe in economies of scale at the local level and therefore directing to connect clusters and communities. We strive for a more conscious and efficient use of potable water and improved sanitation and sharing knowledge to achieve this goal. | Building / District | Nature Based solutions | Commercial product |  |
| | University of Copenhagen<br><br>http://ign.ku.dk/ | Dual Porosity Filtration, water flows horizontally through dual porosity layers for sedimentation, sorption and degradation of contaminants | Building / District | Nature Based solutions | Proof of concept |  |
| | MijnWaterFrabriek<br><br>www.mijnwaterfabriek.nl | Solutions for infiltration and reuse of rainwater and (grey) waste water reuse | Building / District | Engineering Solutions / Technical solutions | Commercial product |  |
| | Zonneterp<br><br>www.zonneterp.nl | The 'Zonneterp' is a design for a neighbourhood that provides for its own energy, biomass and water supply. Basic elements of the design are an energy-producing greenhouse, a settlement of 100 houses and an anaerobic digester. | District | Technical / Nature Based Solutions | Proof of concept |  |

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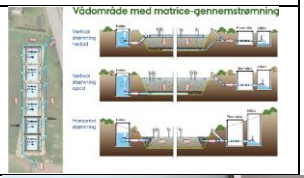
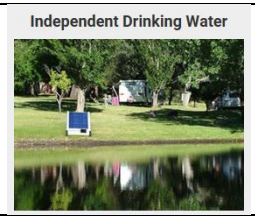
|---|---|---|---|---|---|---|
| | Watermaker<br><br>www.nohnik.nl/portfolio/de-watermaker/ | A vertical urban park that infiltrates and treats rainwater | District | Nature based solution | Proof of concept | |
| | Nordisk Perlite<br>http://www.perlite.dk/ | Filter Soil. Recipe for substrate with documented effect.<br><br>Perlite biofiltration (BF) for Stormwater Management | Building / District | Nature Based | Commercial product |  |
| | Hemels Water<br><br>www.hemelswater.com | Hemels Water makes beer from rainwater. | Building / District | Technological solutions | Commercial product |  |
| | Aquafarm<br><br>www.waterinnovatieprijs.nl/project/aquafarm/ | Aquafarm aim to treat waste water and recover energy, nutrients and other valuable resources | District / City | Technical solutions | Proof of concept |  |
| | Living Machines<br><br>www.livingmachines.com | Living Machine® Technology blends cutting-edge science and engineering with plants and beneficial bacteria to efficiently treat and reuse wastewater, providing lasting water solutions for communities everywhere. | District / City | Technical and Nature Based solutions | Commercial Product |  |
| | Akvola technologies<br><br>www.akvola.com | abvoFloat a technology that focuses on "oil-water separation" and "suspended solids removal" to tackle with hard-to-treat water. Application fields include upstream, oil & gas, refining, desalination, mining, steel and chemicals | Building / District | Technical Solutions | Commercial product (Climate KIC start-up) |  |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Aqualligence<br><br>www.aqualligence.com | Installing low-cost water quality sensors within drinking water system to detect water contamination and providing custom software and consultancies on large scale water system monitoring and security | District / City | Technical Solutions | Commercial product (Climate KIC start-up) | |
| | Desolenator<br><br>http://desolenator.com | Water security. Cost-efficient and low-maintenance water desalination and purification device. It can purify water from any source and remove all contaminants using only solar energy | Building | Technical Solutions | Commercial product (Climate KIC start-up) |  |
| | EcoBrix<br><br>www.ecobrix.nl | Water treatment. AN-bag, a mobile device that can be used for converting domestic wastewater into biogas and clean nutrient-rich water | Building / District | Technical Solutions | Commercial product (Climate KIC start- up) | |
| | EcoGlobe<br><br>www.ecoglobe.de | Waterbase a decentralized ecological water treatment system built underground. It helps to transform household water in an energy efficient way to high-quality reclaimed water for irrigation and cooling in urban area. | District / City | Technical Solutions | Commercial product (Climate KIC start- up) | |
| | Elemental Water Makers<br><br>www.elementalwatermakers.com | A desalination system for turning seawater or brackish groundwater into affordable drinking water on-site using renewable energy. | Building / District | Technical Solutions | Commercial product (Climate KIC start- up) | |
| | MASH Biotech<br><br>http://mash-biotech.com | Bioreactor that converts sludge from the output of wastewater treatment plants to oil that can used in ships, gas or fertilizers that can be used for farming. The process reduced the overall sludge by 50% | City | Technical Solutions | Commercial product (Climate KIC start- up) | |
| | Oulu Water Alliance Ltd (OWA)<br><br>http://owa.fi/ | Owatec has solutions for municipal water and waste treatment in helping to optimize the drinking water production and waste water treatment.<br><br>• Drying sludges by SHS dryer to hygienic granules<br>• PCD water treatment method to disinfect the drinking water<br>• Process optimization | City | Technical Solutions | Commercial product (Climate KIC start- up) |  |

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|---|---|---|---|---|---|---|
| | | | | | | |
| | Small Factory http://www.climatekicemiliaromagna.it/startup/startup/small-factory | Innovative technologies for the water desalinization/purification by solar energy. The system can transform feed water (i.e. water needed in a boiler to be converted into steam) into drinkable water | Building / District | Technical Solutions | Commercial product (Climate KIC start- up) | |

# Appendix II Longlist barriers for Water Smart Cities

Based on literature a long list of barriers is identified. Barriers have been identified in relation to the following themes:

- Conflicting time scales
- Uncertainty
- Awareness and communication
- Fragmentation
- Capacity & Resources
- Case for change
- Costs and benefits

And further specified along the category of actors which impose the barrier onto the business sector, being: Political, Organisational, Institutional, Scientific, Knowledge, Social, Economic, Planning, Technical, Individual, with Individual we refer to barriers which the business community themselves can cause.

| Barriers | Category | Source |
|---|---|---|
| **Conflicting time scales** | | |
| **Time pressure** that politicians put on the responsible officers in coming up with quick solutions to flooding problems in the city, in the context of apparently rapidly changing climate with too many heavy rains in too short time | Political<br>Organisational | Li et al. 2016 |
| **Long-term change in the natural/climate system vs. societal changes and short-termism in decision-making and policies.** Making it difficult to mainstream WSUD in new and existing policies and practices | Institutional<br>Political | Biesbroek 2014 |
| **Uncertainty** | | |
| Uncertainty about **hidden agendas of politicians** | Political | Biesbroek 2014 |
| Uncertainty about the **differences in understanding the problem** | Political<br>Institutional | Biesbroek 2014 |
| Uncertainty about the **rate and speed of water stress** in cities, climate change related extremes events like extreme rainfall, droughts, heat waves | Scientific | Biesbroek 2014 |
| Uncertainty about the quality and quantity, availability and accessibility, legitimacy and credibility of **data and information used in decision-making** | Scientific<br>Knowledge | Biesbroek 2014 |
| **Strategic uncertainty** caused by strategic behaviour of actors in decision-making processes | Institutional<br>Political | Biesbroek 2014 |
| **Institutional uncertainty**, difference in institutional background of the actors participating in policymaking processes | Institutional | Biesbroek 2014 |
| **Awareness and communication** | | |
| Uninformed about **role and the collective (governmental) efforts** on water sensitive design | Individual<br>Institutional | Biesbroek 2014 |
| Conceptual transition from 'engineering approach' to 'ecological approach', **perceptions** of a city as a living ecosystem | Individual<br>Social<br>Organisational | Li et al. 2016 |

| Barriers | Category | Source |
|---|---|---|
| | Political | |
| Lack of **political awareness** | Political | CS4B, 2015 |
| Lack of **communication** of how the project fits within a larger context, thereby not linking it to external drivers for change that may resonate with a wider audience | Individual | Wong / CRCWSC 2014 |
| **Fragmentation** | | |
| **Lack of connection and** coordination among institutions, organizations, individuals and policies at different levels and scales. | Individual Institutional Organisational | Biesbroek 2014 |
| Knowledge **diffuse**, or only partly accessible | Knowledge | Biesbroek 2014 |
| **Responsibility divided** across different organizations; decisions may have to be made at different levels, with decisions on one level having a negative consequence on other levels | Organisational | Biesbroek 2014 |
| Lack of **collaboration or integration** among sectors and professions - organizational structure of the regime, professional practice and even disciplinary education | Organisational Social | Li et al. 2016 |
| Lack of **linkage** to existing management tools and frameworks to increase legitimacy | Individual | Wong / CRCWSC 2014 |
| **Capacity & Resources** | | |
| Lack/inaccessibility of **human resources** - availability of staff, time to become informed, managerial support, skilful and qualified individuals | Organisational | Biesbroek 2014 |
| Lack/inaccessibility of **financial resources** - process finance, finance for implementing | Economic | Biesbroek 2014 |
| Lack/inaccessibility of **information resources** - fundamental and applied research, tacit and local knowledge, data availability, credibility and legitimacy of information | Organisational Scientific Knowledge | Biesbroek 2014 |
| Lack/inaccessibility of **physical resources** - technical measures<br>(Unavailability of technology available to replace vulnerable or unsustainable technology or infrastructure) | Technical | Biesbroek 2014 |
| Lack/inaccessibility of **natural resources** - availability of land | Planning Technical | Biesbroek 2014 |
| Lack of systemic documentation of **capacity** | Planning | Li et al. 2016 |
| Lack of **understanding** of what kind of urban form a Green Infrastructure approach will imply to a city | Technical | Li et al. 2016 |
| Lack of **knowledge** on how to incorporate the new Green Infrastructure into existing urban structure | Knowledge Technical | Li et al. 2016 |
| Lack of **estimations** of the ability of Green Infrastructure to detain and retain water | Technical Knowledge | Li et al. 2016 |
| Lack of **incentive schemes** to stimulate investments in Green Infrastructure | Institutional Political | CS4B |
| **Case for change** | | |
| Lack of routines for **innovative approaches** | Individual, Organisational | Li et al. 2016 |
| Not a sufficient understanding of the **real decision-maker** - who, their needs, their criteria when assessing a business case, who has the power to deliver what you need (their drivers, values and beliefs) | Individual | Wong / CRCWSC 2014 |

| Barriers | Category | Source |
|---|---|---|
| Lack of **demonstrating** the project's **relevance** to a decision-maker | Individual | Wong / CRCWSC 2014 |
| **No clear definition** of what a water sensitive city is, including explanation on how the system works now and what will be different in the future (visualisation of positive change, benefits of the project) | Individual<br>Political<br>Institutional | Wong / CRCWSC 2014 |
| Lack of **own/local context** in business case (issues, drivers, position on water sensitive city transition, local or national/state policy of framework) | Individual | Wong / CRCWSC 2014 |
| Lack of **framing** your issues into the broader water agenda | Individual | Wong / CRCWSC 2014 |
| Lack of **common vision** in project and key messages | Individual | Wong / CRCWSC 2014 |
| Lack of **involving relevant stakeholders**, e.g. political leaders, community groups, media | Individual<br>Social<br>Political | Wong / CRCWSC 2014 |
| Business case **lacks an evidence-base** and stakeholder support | Individual<br>Knowledge<br>Social | Wong / CRCWSC 2014 |
| Lack of clear **"business-as-usual" scenario**, which does not consider the future results of the business-as-usual | Individual | Wong / CRCWSC 2014 |
| Business case lacks **flexibility** in responding to changing agendas | Economic | Wong / CRCWSC 2014 |
| **Costs and Benefits** | | |
| Lack of making the business case relevant for local communities, not identifying **tangible local benefits** | Individual | Wong / CRCWSC 2014 |
| Lack of **presenting costs and benefits** to the broader community; size of costs and benefits, expected changes, differentiate or rank options | Economic<br>Individual<br>Social | Wong / CRCWSC 2014 |
| Lack of **identifying and assessing** the benefits from the perspective of the end users | Economic<br>Knowledge | Wong / CRCWSC 2014 |
| No **valuation** of costs and benefits | Economic<br>Knowledge<br>Scientific | Wong / CRCWSC 2014 |
| Lack of a **robust evaluation** | Economic<br>Knowledge | Wong / CRCWSC 2014 |
| Lack of understanding of the **short- and long-term** benefits, which stakeholders will pay and which will benefit | Economic<br>Knowledge<br>Social | Wong / CRCWSC 2014 |
| Business case lacks **linkage** to a funding source | Individual<br>Economic | Wong / CRCWSC 2014 |
| **Financial lock-in** effects of past investments | Economic | CS4B |
| Lack of **usable cost-benefit methods** | Economic | CS4B |