Water for smart Livable cities

How rethinking urban water management can transform cities of the future

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EXECUTIVE SUMMARY

Good water management can make cities healthier places to live, resilient towards climate change and more sustainable overall. Without proper sanitation, sewerage and clean water supply, there is no liveable city. Placing water at the core of the city's urban planning and investments creates a strong foundation for sustainable growth. When urban planners and water managers join hands, it increases chances of developing long-term solutions, which successfully integrate the role of water with the needs of both local citizens and nature.

Ensuring sustainable water supply and wastewater treatment in cities
Urban population growth is increasingly putting pressure on urban water supply. In order to overcome water stress, knowledge of quantity and quality of available water resources is important. A well-maintained pipe network constructed of high quality materials is also essential and digitalisation and data utilisation can increase efficiency of supply.

Urban population growth also means wastewater treatment plants must treat an increasing volume of wastewater. Sewage collection and treatment systems play a key role in creating liveable cities and enables water related recreational activities such as harbour baths. Finally, wastewater treatment can supply the city with green energy and recovery of scarce resources.

Stormwater management contributes to both resilience and liveability
Climate change is putting increasing pressure on wastewater infrastructure in cities around the world. A common challenge is to ensure sufficient capacity in the sewer systems to prevent overflows in times of heavy rain. A combination of solutions are often needed to prepare cities for extreme weather events. When stormwater management is integrated in urban planning and design it can lead to increased resilience to climate change, efficiency, liveability and a sense of place for urban communities.

Activities in the open land outside the city also has an enormous impact on the city itself. Strong cooperation with different stakeholders at basin scale can enable joint decision making across administrative boundaries.

Digital transformation, urban water governance and partnerships
Digitalisation of urban water management increases transparency, innovation and liveability. New technologies and innovative solutions go hand-in-hand with regulation and organisational development. Successful water management requires strong governance structures. In addition to environmental standards, regulation of the water sector needs to include a focus on financing mechanism, water prices and transparency.

Working together in partnerships when developing water solutions for smart and liveable cities often leads to more innovative and efficient solutions and ultimately improves the framework for innovation and prosperity.

Find inspiration for your own urban water projects
This white paper features lessons learned from different Danish stakeholders within urban water management. It is meant to serve as a tool for inspiration for creating innovative water solutions, which contribute to smarter and more liveable cities.

More white papers about water related topics will continuously be made available at **www.stateofgreen.com/publications**

"I believe water is the key to creating cities that are both sustainable and attractive places to live. Caring for the environment while managing well-functioning cities that are resilient, healthy and attractive places to live is a challenge facing cities all over the world - but it also represents opportunities."

Lea Wermelin, Minister for Environment, Denmark

To create liveable cities, we need to combine smart water solutions and climate adaptation measures with exciting urban development. The cases in this publication from Copenhagen, Aarhus, Viborg, Kolding and many other Danish cities are prime examples of how this can be done.

Water as a catalyst for sustainable development
Denmark was a strong advocate for setting a UN Sustainable Development Goal on Clean Water and Sanitation (SDG6). Water also plays into many of the other Sustainable Development Goals. For instance, it is difficult to imagine achieving SDG 11 on Sustainable Cities and Communities without also implementing solutions for sustainable urban water management.

Danish companies and water utilities are committed to implementing the Sustainable Development Goals in their work. For instance, Aarhus Vand – the water utility of Denmark's second largest city – is the first water utility in the world to be certified according to the Sustainable Development Goals. BIOFOS – the wastewater treatment company of Greater Copenhagen – actively integrates Goal 17 on Partnerships in their activities, while VCS Denmark in Odense has Goal 12 on Responsible Consumption and Production as one of their priority goals.

Water and climate action
We want to reduce Denmark's greenhouse gas emissions by 70 percent by 2030. And while our emissions only account for a fraction of the total greenhouse gas emissions worldwide, we believe that it is important to set an example for other nations to be inspired by and follow. The same goes for our water sector. Globally, the water sector accounts for 4 percent of the world's total electricity use, so energy and resource recovery as well as greenhouse gas emissions from wastewater are also areas we need to address if we are to move our planet and our cities in a more green and sustainable direction.

Together with the sector, we have set an ambitious goal for the Danish water sector to become both energy and climate neutral by 2030. It is an ambitious, yet realistic target as water utilities are already focusing on efficient supply of drinking water and wastewater treatment plants are being turned into energy- and resource recovery facilities, providing the city with green energy.

Collaboration and partnerships as drivers of urban transition
Denmark has a long tradition for developing and implementing urban water and climate adaptation solutions which succeed in solving more than one problem at the time – often in close collaboration between authorities, utilities, organisations, private companies and citizens. This has brought us far and we are eager to share our experiences with other countries.

Denmark will be hosting the IWA World Water Congress & Exhibition in September 2022. I invite you to join us for a week of interesting discussions on how we can shape our water future together. I am sure you will enjoy our clean and tasty drinking water and perhaps even try a swim in one of our harbour baths yourself.

Until then, I hope you feel inspired by this white paper.

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1. WATER FOR SMART LIVEABLE CITIES

Water is key to creating smart cities that are both liveable and sustainable

Proper water management can make a difference for cities that are healthier to live in, resilient towards climate change and more sustainable overall. Digitalisation connects water management to the smart city agenda and increases transparency, innovation and liveability.

Today, more than half of the world's population live in cities. The United Nations estimate that by 2050, this will increase to 70 percent. Water is fundamental for both life – including modern, urban life – and economic growth across sectors. According to World Economic Forum's Global Risk Report 2020, water-related issues such as extreme weather, natural disasters, drought, and failure to adapt to climate change are among the greatest global risks to the well-being and prosperity of mankind.

Ensuring basic delivery of services for people and production, while at the same time protecting the surrounding water resources is a key task for urban water managers. This must go hand-in-hand with planning and managing well-functioning cities that are resilient, healthy and attractive places to live.

Urban water managers all over the world share these challenges. In Copenhagen – the host city of the International Water Association's (IWA) World Water Congress & Exhibition in 2022 – and other Danish cities, water managers are constantly working towards creating better cities, and they are committed to sharing experiences with other cities worldwide.

Water governance, technology development and daily operations in Denmark is based on a high level of trust, engagement and enforcement of regulations which ensure public legitimacy. Over the past 50 years, a professional effort has been made to streamline and further develop the water sector to provide environmental benefits, effectiveness and efficiency and to support sustainability efforts. And in recent years, to also contribute to an overall green transformation of society in a manner which promotes economic growth and employment.

Megatrends shaping the water sector
By the onset of the 2020s, three new agenda-setting megatrends are shaping the international water sector as well as the Danish:

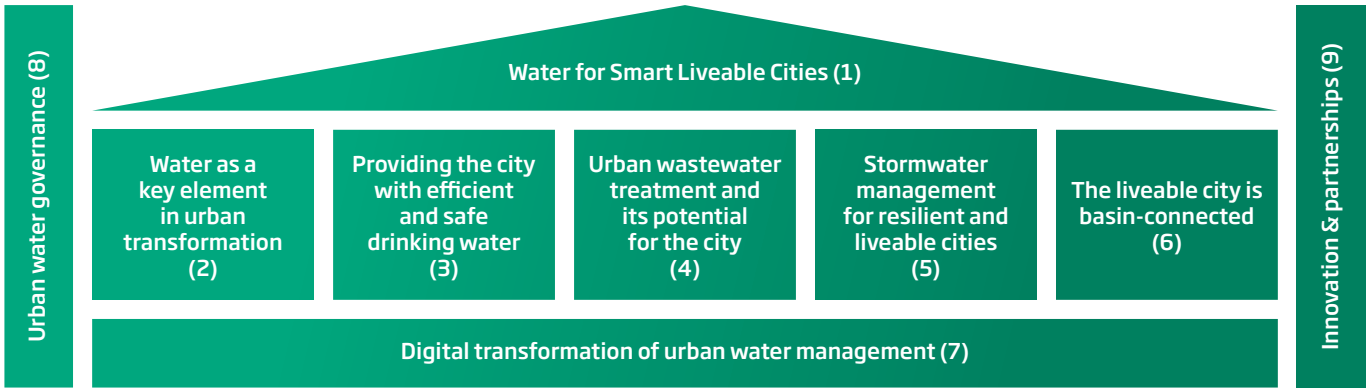
- A call for **sustainability** is seen all over the world. Many of the 17 UN Sustainable Development Goals (SDGs) directly or indirectly depend on finding sustainable solutions for water, and there is even a dedicated goal for clean water and sanitation. The SDGs are crucial to the overall vision of Water for Smart Liveable Cities, along with a number of key elements that are illustrated below and further discussed in the subsequent chapters of this white paper.

- A strive for **liveability** through use of multifunctional blue-green infrastructure, which offers many benefits to urban society, including improved local climate resilience through reduced combined sewer overflow and flooding, improved urban amenities, and decreased environmental life cycle impacts of water infrastructure. This strive is embedded in IWA's Principles for Water-Wise Cities.

- **Digitalisation**, which is currently transforming water systems from passive, single-purpose infrastructure elements into active and adaptive units that can respond differently according to situation and be planned, designed and operated in an integrated manner. This connects the water sector to the broader smart cities agenda, which strives at increasing citizen involvement, and potentially contributes to making the water sector more efficient, more innovative and more sustainable.

These megatrends are also reflected in the European Union's 'Green Deal', which aims to achieve carbon-neutrality by 2050 and sets ambitious targets for zero pollution, a cleaner environment and improved biodiversity. This is mirrored by the Danish Government's green transition policy which aims to reduce the country's total CO_2 emissions by 70 percent by 2030, and sets a specific target for the Danish water sector to become energy and climate neutral by 2030.

Key elements of Water for Smart Liveable Cities which are detailed in chapters throughout this white paper



Water and the UN Sustainable Development Goals
The United Nations (UN) defines water as one of the 21st century's biggest challenges. As a result, one of the 17 Sustainable Development Goals (SDGs) is dedicated to 'Clean Water and Sanitation' (SDG 6) and promotes universal and equitable access to clean water and contemporary sanitation services. Many of the other SDGs also indirectly depend on sustainable water solutions which highlights the importance of SDG17: 'Partnerships for the goals'.

1 Regenerative water services
- Replenish water bodies and their ecosystems
- Reduce the amount of water and energy used
- Reuse, recover, recycle
- Use a systemic approach integrated with other services
- Increase the modularity of systems and ensure multiple options

2 Water Sensitive Urban Design
- Enable regenerative water services
- Design urban spaces to reduce flood risks
- Enhance liveability with visible water
- Modify and adapt urban materials to minimise environmental impact

3 Basin connected cities
- Plan to secure water resources and mitigate drought
- Protect the ecological health of water resources
- Prepare for extreme events

4 Water-wise communities
- Empowering citizens
- Professionals aware of water co-benefits
- Transdisciplinary planning teams
- Policy makers enabling water-wise action
- Leaders that engage and engender trust

17 Principles for Water-Wise Cities
The International Water Association has developed this comprehensive approach to sustainable urban water management, climate resilience and urban liveability. The above 17 principles represent steps towards sustainable and water-wise cities, divided into four levels of action. In addition, five 'building blocks' guide urban stakeholders to deliver sustainable solutions: Vision, Governance, Knowledge & capacity, Planning tools, and Implementation tools.

2. WATER AS A KEY ELEMENT IN URBAN TRANSFORMATION

Water investments help cities grow sustainably and become attractive places to live

Cities in both developing and developed countries benefit from putting water at the core of their urban planning and investments - and the UN Sustainable Development Goals provide a perfect framework.

During the 1960s, cities were redesigned to make room for our new best friend: the car. Today, faced with challenges and opportunities driven by climate change, many cities are placing water closer to the core of urban planning and design.

Water is not only key to life but can also be a key element in urban transformation and progress. Without proper sanitation, sewerage and clean water supply, urban civilization gets on the verge of a decline. Take the city of Cape Town, for instance: After years of drought, this modern capital and attractive tourist destination came close to facing a 'day zero' of clean water supplies in 2017-2018, which led to a sudden fear of a breakdown and social instability.

The Sustainable Development Goals, especially SDG 6 on 'clean water and sanitation' and SDG 11 on 'sustainable cities and communities', provide a perfect framework for urban planning and could serve as guiding principles for future investments. The benefits for cities investing significantly in contemporary water management are many.

The presence of water increases biodiversity

The impact new urban development will have on the surrounding nature should also be considered during the planning phase. When urban planners, architects, landscape designers and water managers join hands early in the planning phase of urban areas, it increases chances of developing long-term solutions which successfully integrate the role of water in that particular area with the needs of both local citizens and nature. Experience from Copenhagen also show the positive impact that the presence of open water bodies have on biodiversity in the city.

From dirty gutters to social magnets

History has shown that cities which have given water a high priority, have a strong foundation for sustainable growth. Those who keep water at the core of their planning, will also be the winners of the future.

Once water systems are improved, access is democratised and gutters are cleaned, urban water changes from a nuisance and a potential health risk into something that makes the city highly attractive.

In cities that have successfully integrated water in their urban planning, urban canals, rivers, lakes and harbours now have a magnetic effect on people. If a home allows for a glimpse of the sea or a piece of urban water, the property value will be significantly higher. And in cities like Berlin, Copenhagen, Amsterdam, Stockholm and New York, riverbanks and waterfronts have become urban oases where people gather to socialise. In both Seoul and Madrid, motorways have been removed and turned into open, urban rivers with lots of recreational value for citizens and tourists.

Towards full circularity

This development – along with investments in flood-risk management – is a key driver for current and future investments in urban water solutions. It is also a significant reason why more and more cities are adapting to climate change through nature-based blue-green solutions with added recreational value.

The next step in this urban water-based transformation is full circularity. Visionary city leaders have set up circular water programs, where climate adaptation measures and water systems become integrated and further included in smart resource cycles, enabled by new digital solutions.

Harbour baths as catalysts for urban development, Copenhagen, Denmark

The first swimming facility in the Copenhagen Harbour area opened in 1785 and throughout the 19th century several more were established. However, in 1954 the pollution level had increased which – combined with improved knowledge of bacteriology and viruses – let to a ban on all swimming activities in the harbour. The ban lasted until 2002 when the opening of the current harbour bath was made possible through improved wastewater management and the city's efforts to mitigate combined sewer overflows (CSOs). Underground detention structures were established and equipped with transmitters to indicate overflow into the harbour. The transmitters continuously send information to a central computer and based on 3D-modelling, the City of Copenhagen can determine whether the limits in the Bathing Water Regulation have been exceeded and a red flag should be hoisted at the swimming facilities. Citizens can access this information online or via an app. Today, more than 100,000 people enjoy a swim in one of the city's swimming facilities each year as well as participate in recreational activities such as kayak-polo, canoeing, kayaking and fishing. The area along the city's inner harbour is now one of the trendiest spots in the city and property values have more than doubled.

(Courtesy: City of Copenhagen, HOFOR – Greater Copenhagen Water Utility, DHI, Krüger, Rambøll, COWI, NIRAS, JDS Architects and Bjarke Ingels Group)

Image credit: TREDJE NATUR

Water and biodiversity in the city, Copenhagen, Denmark

The City of Copenhagen wants to address both climate change and the biodiversity crisis with the help of urban nature. As a part of the city's climate adaptation strategy and the implementation of its cloudburst management plan, the city has thus also decided to focus on increasing urban nature and biodiversity. As rainwater and urban nature is closely connected, increasing the presence of urban nature in the future will also contribute to creating more natural water circulation. The implementation of a city-wide plan, which will enable the city to manage a 100-year storm event provides a unique opportunity to utilise the synergies between water management, green areas and social infrastructure. This is done by deliberately integrating green and blue infrastructure as part of the design of the cloudburst projects. Over time, the increased use of green and temporary blue spaces will also contribute to minimising urban heat island effect by replacing hard surfaces with softer green surfaces. A transformation of the city with fewer gray roads, squares and urban spaces and more trees, green roofs, grazing guilds etc. will also have a positive effect on biodiversity.

(Courtesy: City of Copenhagen and SLA Architects)

Photo credit: Carsten Ingemann

sØnæs - climate change adaptation creates attractive park and water landscape, Viborg, Denmark.
For years, a 10 ha recreational area on the edge of the Danish city Viborg was home to swamped football fields, and the adjacent lake suffered from high amounts of phosphorous and nitrogen.

Today, the area has been transformed into a public park, protecting the city against damages from cloudbursts and reducing the amount of nutrients released into the lake. A purification pond was established to simultaneously retain large amounts of stormwater and decrease flood risks. The technical stormwater elements have been integrated in a soft, undulating terrain which retains the natural characteristics of the area.

The utility's costs were the same as it would have been for a traditional stormwater project but the multipurpose design meant that half of the utility's contribution covered elements which also had a recreational value. The municipality and a private fund financed the purely recreational facilities.

The project demonstrates how climate adaptation can accommodate both stormwater management and purification as well as social and recreational benefits. The successful integration of these features has transformed sØnæs into a key destination point for the region.

(Courtesy: Utility company 'Energi Viborg', Viborg Municipality, LYTT and WSP with financial support from Realdania and The Danish Foundation for Culture and Sports Facilities)

Photo credit: Rasmus Hansen, Google Photographer

A city designed around rainwater, Aarhus, Denmark

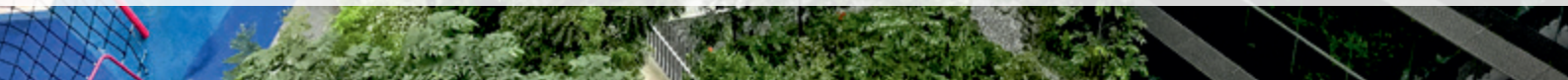
Nye is a new suburb of Aarhus, Denmark's second largest city, where rainwater has been considered a resource right from the start of the development. Rainwater from roofs, roads and other areas is collected in open trenches and runs through small ponds before it is collected in a small lake, which in reality is a beautiful rainwater basin. In the event of a cloudburst, there is capacity in the lakes for the storage of rainwater corresponding to a 100-year rainfall event. From the lake, water is channelled into a treatment plant where it undergoes a 3-step treatment process before being distributed to the area's homes in a separate pipe network – the first place in Denmark to do so. When using multiple water types, water safety is paramount. Therefore, the rainwater pipes are purple, to prevent them from being inadvertently connected to the drinking water system, and various backflow protections are installed. Inside the homes, the treated water is used for toilet flushing and laundry. This has reduced the need for drinking water supply by 40 percent in an area with limited groundwater resources. Nye demonstrates a completely new and holistic approach to rainwater in an urban area.

(Courtesy: Aarhus Vand, Tækker Group, Silhorko-Eurowater and COWI)

Hydrological building design promotes both social and environmental sustainability, Singapore

To accommodate the need for public housing in Singapore, an empty lot was transformed into what is now Kampung Admiralty. The uniqueness of Kampung Admiralty stems from its design which focuses on both social and environmental sustainability. It encourages the elderly residents to engage in an active lifestyle among younger generations, but it is also part of a greater effort to increase environmental sustainability. The hydrological design of the building allows nearly 4 million litres of water a year to be harvested, stored and reused for irrigation. The rainwater travels through a large series of gardens which function as a vegetative stormwater filter. Furthermore, an eco-pond improves biodiversity and provides a cooling effect in an otherwise warm, urban climate. With its ambitious amounts of greenery, Kampung Admiralty stands out in a densely populated urban area. It is a prime example of how circular thinking can be used to lessen the impacts of increasing urbanisation.

(Courtesy: Ramboll Studio Dreiseitl and WOHA Architects)



3. PROVIDING THE CITY WITH EFFICIENT AND SAFE DRINKING WATER

A sustainable and liveable city requires safe, efficient and sufficient drinking water supply

Ensuring sufficient supply of clean drinking water for a growing urban population is a challenge for many cities around the world. The Danish model for urban water supply may be a source of inspiration as it ensures efficient and safe supply of high quality water in a transparent and democratic manner.

Population growth and urbanisation is increasingly putting pressure on urban water supply. By 2025, half of the world's population will be living in water-stressed areas according to estimates by the United Nations. Furthermore, the recent global health crisis due to COVID-19 underscores the importance of access to clean water to ensure a healthy population.

Inspiring the world with a sustainable drinking water resource: Groundwater
In order to overcome water stress in rural and urban areas all over the world, knowledge of quantity and quality of available water resources is important. Groundwater is available in many countries but is often not used or overexploited due to lack of knowledge or poor management. Drinking water supply in Denmark is based entirely on groundwater, which is a sustainable, high quality source as it is less susceptible to short-term changes in rainfall patterns than surface water. This has led to the implementation of intensive groundwater mapping, monitoring and protection programmes.

Denmark is relatively densely populated with very intensive farming activities, causing a range of challenges in terms of groundwater contamination and eutrophication. An emerging challenge is finding a wide range of both known and new pesticides in groundwater. This confirms the need for both a robust monitoring system and for developing competencies to handle pesticides, which is therefore areas of great focus. At the same time, long-term efforts with targeted information campaigns have created a strong awareness of the origin of Denmark's drinking water. This strengthens national willingness to protect this precious water source.

Securing high quality drinking water with low carbon footprint
The various protection measures in Denmark have resulted in high groundwater quality, which allows for production and distribution of drinking water without the need for disinfection. The groundwater is treated by aeration, followed by single or double rapid sand filtration, which includes an array of complex microbial processes that can remove contaminants such as pesticides.

The water sector has an important role to play in reducing carbon emissions globally. Biological rapid sand filters - which have been used, refined and optimised in Denmark for decades - are now receiving increased international awareness also due to their low carbon footprint.

To maintain a high water quality all the way from well to tap, the system has to be well maintained and constructed of high quality materials. To support this, a management support system such as 'Water Safety Plans' (DDS), which all major water utilities in Denmark are required to use, is useful.

Reducing urban water loss to meet future demand
An important means to meet the rising demand for drinking water in cities is to reduce urban water loss and Non-Revenue Water (NRW). Today, 25-50 percent of all distributed water worldwide is either lost or never invoiced. This poses both a threat to the environment - especially in areas with high water scarcity - and a threat to the financial viability of water utilities due to revenue losses and unnecessarily high operating costs. In Denmark, private-public cooperation has led to advanced non-revenue water technologies such as smart meters, valves, pumps and pipes as well as tools and methods for planning, monitoring and managing water loss. Together with an economic incentive for water utilities to reduce their water loss to less than 10 percent, the country has achieved one of the world's lowest levels of NRW with a consistent national average of just 6-8 percent.

Pursuing increased efficiency through data, digitalisation and innovation
Danish water utility companies operate with a high level of transparency, and information on both water prices and water quality is publicly accessible. This transparency has migrated into development of advanced drinking water databases with information on e.g. water quality, daily operational data, distribution systems etc. Data availability sparks efficiency improvements through increased digitalisation, machine learning and data-based decision making. Furthermore, fast and efficient exchange of data clears the way for public-private-partnerships on innovation.

Reducing urban water loss in Changchun, China
Reducing loss of drinking water is a national priority in China where the Central Government has mandated cities to keep their NRW-levels at 12 percent or less. In Changchun, Jilin Province, the Changchun Water Group (CWG) is dedicated to achieve this goal. In 2017, the CWG therefore initiated a collaboration with its Danish sister city Hjørring and a number of Danish companies. To document the original level of water loss, online monitoring equipment was installed and digital surveys of flow and pressure was carried out over a period of 11 months in two of the CWG's supply areas. This documented a total NRW-level of up to 35 percent with commercial losses accounting for approx. 15 percent and physical losses accounting for the rest. To reduce this level, a number of technology and service solutions – well-documented under Danish conditions – are expected to be applied. Reducing NRW to 12 percent would lead to an annual value creation of approx. EUR 20 million. Based on experience from the two demonstration sites, the investment in NRW service and technology solutions would have a return on investment of around 3 years.

(Courtesy: Hjørring Water, Krüger-Veolia, AVK, Kamstrup, Grundfos, Leif Koch and DANVA)

Smart metering saves 4 million litres of drinking water in water scarce area, Saldanha Bay, South Africa
Saldanha Bay is located in a water scarce part of South Africa north of Cape Town. During 2017, the region faced one of the worst droughts in its history. The municipality knew they needed to start saving and managing water resources differently in order to ensure sustainability of their supply to the community. Along with severe water restrictions, the municipality decided to invest in a smart water metering solution with real-time data to bring down water loss. The project started in 2017 with a pilot in Vredenburg where a fixed network with one concentrator and 2,558 meters was installed. Today, the utility is notified by alarms from the meters whenever leaks or bursts occur in their distribution network. Within the first 30 days of operations, 317 alarms were identified and fixed within just hours of occurrence. The real-time monitoring of consumption and water balances has resulted in an immediate drop in the municipality's water loss – more than 4 million litres have been saved so far. After the successful pilot, 30,000 smart meters will be installed over the next years.

(Courtesy: Kamstrup A/S)

4. URBAN WASTEWATER TREATMENT AND ITS POTENTIAL FOR THE CITY

From wastewater treatment to resource and energy recovery

80 percent of all wastewater globally is not collected and treated adequately. This poses a significant negative impact on both environment and human health. Combined with new challenges from a changing climate, a new approach to urban wastewater management is required.

Ensuring high quality treatment to protect people and ecosystems

Urban population growth means wastewater treatment plants (WWTPs) must treat an increasing volume of wastewater in order to secure the health of the local population and water environment. It is important that both large centralised and small decentralised plants can discharge the treated wastewater without harming the recipient, whether it is the sea or a small stream.

Danish WWTPs operate under strict requirements for improved treatment of wastewater. The wastewater sector has spent many years refining and developing technologies that treat wastewater to a high level (through primary, secondary and tertiary treatment) to ensure that it does not contaminate the recipients. Combined with a taxation system which incentivises WWTPs to treat the wastewater beyond the legal requirements, this has resulted in outlet concentrations which contain far less discharged material (only 20-70 percent compared to the legal limits), according to a study from the Danish Water and Wastewater Association (DANVA).

Liveable cities depend on successful wastewater management

Sewage collection and treatment systems play a key role in creating liveable cities where recreational activities are possible along the city's harbours, lakes or rivers. In Denmark, blue-green cities, harbour baths and other recreational facilities would not have been possible without well-managed wastewater infrastructure.

Climate change is putting increasing pressure on wastewater infrastructure in cities around the world. A common challenge is to ensure sufficient capacity in the sewer systems to prevent overflows, especially in times of heavy rain. When redesigning the wastewater infrastructure, focus should also be on separating and treating stormwater from roads and other contaminated surfaces to prevent pollution.

Powering the city through energy recovery

In alignment with the country's overall green transition strategy, the Danish water sector aims to become energy and climate neutral by 2030. To fulfil this ambition, a green conversion of the wastewater sector is currently taking place in Denmark. The starting point has been to focus on energy efficiency and energy recovery. Today, several plants are now net producers of energy, where the sludge is used to produce biogas and electricity and excess heat is used in the district heating system. Recovery of energy by using heat pumps is also a new area for innovation and development.

From wastewater treatment plants to resource recovery facilities

In the future, wastewater treatment need to be designed in a way which allows for not only energy but also other resources (e.g. phosphorous) to be extracted and included in the circular economy while also ensuring that harmful substances do not reach the recipient.

Considering wastewater as a resource is a relatively new perspective and new knowledge and technology is still needed to recover valuable resources in the wastewater on a commercial scale. Research and development in Denmark is dedicated to this field. Advanced membrane technology is already undergoing rapid development but new specialised technologies are still needed. Sorption technology that enable collection of low concentrations of valuable substances or pollutants will also have a prominent place in the future WWTP. For instance, new bacterial cultures need to be developed to produce base chemicals etc.

WWTPs can be seen as production lines, where usable substances e.g. phosphorus and ammonium are removed along the way and other products are removed and further processed e.g. organic matter to produce biogas or base chemicals which can be used for high priced products in the pharmaceutical industry etc. Furthermore, wastewater from industries must be carefully reviewed to ensure that valuable components are separated. Of course, not all substances in the wastewater can be recovered as some will still need to be removed and degraded for the sake of the purity of the products and the discharged wastewater.

Solrødgård - a fully covered WWTP designed in harmony with nature, Hillerød, Denmark

The old WWTP in Hillerød was challenged by a growing city and complaints about bad smell and noise. Building a new traditional plant outside the city would simply cause the problem to reoccur in 30 years. Instead, a 100 percent covered WWTP was built in a 52 ha area 4 km from the city centre. The new 'Solrødgård Climate and Environment Park' is home to all of the utility's activities; district heating, waste, water and wastewater. All processes are encapsulated and equipped with advanced DIMS control systems, which provides maximum control of odour and nitrous oxide emissions. Surplus energy goes to the district heating grid and helps displace fossil fuels. The vision was to draw inspiration from nature's integrated systems where everything is produced from renewable energy sources. The plant's exit strategy is to leave a well-functioning wetland in 40-60 years' time, where the biological and recreational aspects are strengthened compared to today. The master plan is designed with respect for the surrounding nature with the functional areas as 'pockets' in this contiguous landscape. A new neighbouring district is under development with a hospital, railway station and 5000 homes and businesses. Real estate prices are up to 30 percent higher than if the plant had been a traditional WWTP.

(Courtesy: Hillerød Forsyning, Krüger, Stjernholm, DHI, WSP, Gottlieb Paludan Architects and Henning Larsen Architects)

WWTP contributes to circular economy in the urban water cycle, Copenhagen, Denmark

Wastewater treatment can contribute significantly to the implementation of circular economy principles in the urban water cycle of Greater Copenhagen. A new project - VARGA – aims to transform the traditional treatment plant Avedøre WWTP (350,000 PE) into a Water Resource Recovery Facility, by implementing several innovative technologies within wastewater treatment, nutrient recovery and greenhouse gas reduction. Major elements in the project include prefiltration in full scale, P recovery in pilot scale and active reduction of N_2O. As part of the project, a Life Cycle Assessment and an eco-efficiency analysis has been conducted. Initial results show that the Total Added Value is higher after implementing the VARGA concept compared to business as usual – without compromising the treatment efficiency. Circular economy is central for the project and the experiences gained further contribute to the Danish national goal of an energy and climate neutral water sector in 2030 as well as the UN agenda on sustainable development.

(Courtesy: BIOFOS, EnviDan, Unisense Environment, ARC and DTU Environment with financial support from the Danish Eco-Innovation Programme)

5. STORMWATER MANAGEMENT FOR RESILIENT AND LIVEABLE CITIES

Creating resilient and liveable cities through stormwater and cloudburst management

As the climate changes and the number and frequency of cloudbursts and other extreme weather events increase, so does the need for smart, multifunctional stormwater management solutions which can protect the city and provide multiple co-benefits.

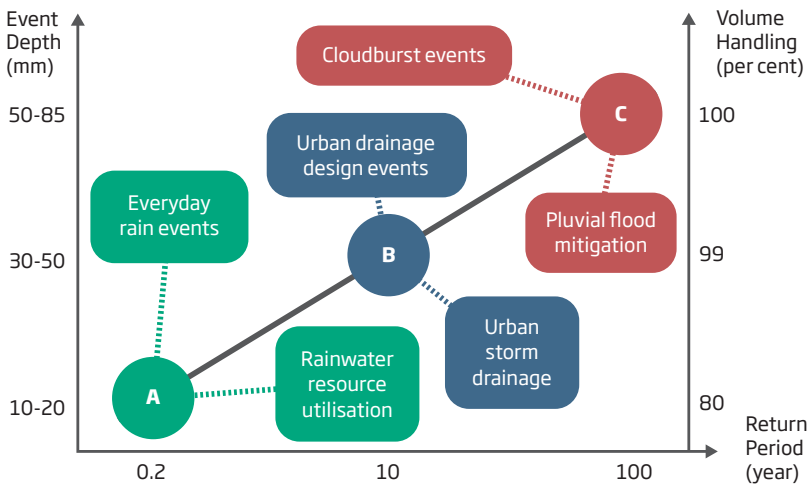
General principles of water infrastructure in the liveable city
Water management in the liveable city is dependent on hydraulic infrastructure both below and above the surface. Many different professionals therefore influence planning and design processes related to stormwater management, and decisions are often made at the interface between three main considerations (as illustrated in the figure below): (A) rainwater resource utilisation considering 'everyday rain events', (B) urban storm drainage considering 'design events', and (C) pluvial flood mitigation considering 'cloudburst events'. Cloudbursts are short-duration, intense rainfall events that exceed the capacity of the underground sewer system and can cause flash flooding and disruption of critical functions in the city. Solutions rely on a combination of the processes; storage, evapotranspiration, infiltration, transportation (conveyance) and purification.

Stormwater management - everyday rain and design events
During everyday rain events and design storms in Denmark, runoff is traditionally collected, transported and delayed in underground pipe networks (combined or separate sewers). These are now increasingly being supplemented by Nature Based Solutions (NBS) above ground, which provide amenity value and are combined with the traditional sewer systems to create smart water solutions, which also contribute to more attractive urban spaces for local citizens.

Cloudburst management
A combination of solutions are often needed to prepare cities for extreme weather events such as cloudbursts. Depending on the local conditions, these can range from underground tunnels and detention basins to including urban spaces for detention above the surface.

Following a major cloudburst event in 2011, the City of Copenhagen adopted a comprehensive Cloudburst Management Plan in 2012. The plan suggests a combination of solutions that will both protect Copenhagen and make the city a more attractive place to live. According to the calculations behind the plan, water volumes from cloudbursts are so massive that no existing storage capacity in Copenhagen (e.g. green spaces, car parks, or similar) would be large enough to contain the water. During cloudburst events, the major part of the precipitation must therefore be transported to the harbour while only a minor part will be channelled to existing green areas or Nature Based Solutions. The plan suggests measures such as emergency flood channels, constructed canals and tunnels reserved for stormwater as a means to reduce damage in the city and the costs of managing stormwater.

Stormwater management's contribution to urban transformation and increased liveability
The selection of suitable areas used for storage of rainwater and stormwater runoff must take place in conjunction with the detailed urban planning in the various parts of the city and with respect for historical, cultural and aesthetic interests. When creating water infrastructure in the liveable city, the IWA's 'Principles for water-wise cities" (illustrated in chapter 1) may be applied to ensure that water is integrated in city planning and urban design to provide increased resilience to climate change, efficiency, liveability and a sense of place for urban communities. This transformation is already well underway in Copenhagen and in many other Danish cities.



The 3-point approach
Pinpointing three main domains where decisions related to stormwater management take place.

Sørup, H.J.D, Lerer, S.M., Arnbjerg-Nielsen, K., Mikkelsen, P.S. and Rygaard, M. (2016) Efficiency of stormwater control measures under varying rain conditions: Quantifying the Three Points Approach (3PA).

Climate adaptation brings a traditional park up to date, Frederiksberg, Denmark

Following severe flooding after a cloudburst in July 2011, Frederiksberg Municipality in Copenhagen decided to use green urban solutions to store rainwater as part of the municipality's climate adaptation plan. The Lindevang Park is a climate adaptation project which stores rainwater, increases the recreational value for the park's visitors and contributes to a welcoming and safe urban environment. A ditch collects the water from a 12,000 m^2 area and together with a surface basin in the park, it forms a storage facility of 1,850 m^3. The ditch is planted with apple trees and black currant to form a public fruit garden. This has reduced areas of concealment and improved visibility which offers visitors a feeling of safety. Just outside the park, a square has been transformed to store 200 m^3 of rainwater on the surface with an iconic 80 metres long concrete wall formed as the Fibonacci spiral for the neighbouring schools to practise mathematics with. On the top of the concreate wall, water runs through a trench for children to play with. The water also cancels out traffic noise for the benefit of visitors who use the square to enjoy food and drinks.

(Courtesy: Frederiksberg Municipality, Frederiksberg Forsyning, Realdania, Marianne Levinsen - Landscape Architect and NIRAS)

Photo credit: Ulrik M. Eriksen

Grand Cloudburst Tunnel Projects in the calcareous underground of Copenhagen, Denmark

Two new 'highways for stormwater' are under construction in the Copenhagen underground. As a part of a cloudburst management plan for the Danish capital with a funding of approx. 1.47 billion EUR, the utility companies HOFOR and Frederiksberg Forsyning have initiated two large-scale cloudburst tunnel projects. The two independent tunnels will be drilled at a depth of 12-20 meters below sea level through the calcareous underground beneath the urban districts of Valby and Vesterbro. The tunnels will be up to three meters in diameter and the main purpose is to prepare the city for rare extreme rainfall events. During such cloudbursts, the tunnels will lead stormwater away from urban districts as well as residential neighbourhoods and discharge it into Copenhagen's harbour. At the same time, the two tunnels will also contribute to draining the increasing amounts of everyday rain that are expected due to climate change. An international team of consultants will help execute the highly complicated projects.

(Courtesy: HOFOR – Greater Copenhagen Utility, Frederiksberg Forsyning, NIRAS, GEO, Babeng and Jacobs)

6. THE LIVEABLE CITY IS BASIN-CONNECTED

Overcoming challenges in urban water management through a basin-wide approach

A city is not an island. To secure water supply for people, protect water quality in and beyond the city and prepare the city for extreme weather events, it is important to understand that cities are closely connected to their surrounding basins.

Securing water for a growing urban population

More than half of the world's population now lives in cities and often cities do not have sufficient water of adequate quality within the city limits to secure water for consumption. This can be a serious constraint on the health of the population and economic growth.

In order to secure availability of water, many cities need to take action by bringing in water from outside the city limits. In Denmark, national action has been taken to secure knowledge of water resources and since 2000, mapping of groundwater resources has been the backbone of groundwater protection plans, partly financed by a tax on drinking water. Data from water planning, monitoring and risk assessment are freely available in Denmark which supports a shared and basin connected effort on groundwater protection.

Cooperation with stakeholders at basin scale is necessary in order to harvest the benefits from the shared information about the quality and availability of surface and groundwater and to share the resources between the different users in the basin, while also ensuring a sufficient amount of water in natural water bodies such as rivers, lakes and wetlands.

The International Water Association has developed an Action Agenda for Basin Connected Cities. The Action Agenda builds on IWA's 17 Principles for Water-Wise Cities. It highlights three risk factors that need attention by urban stakeholders:

1. To secure water for consumption and production in cities
2. To protect water quality
3. To prepare for and respond to extreme events

Water does not respect administrative borders

This is a very simple principle, yet often difficult to follow in daily water management practice. To ensure proper water quality, urban water managers need to pay attention to the basin area the city is connected to and where the city gets its water from. In Denmark, there is a tradition for cooperation between different stakeholder groups across administrative borders as a means to secure a healthy water environment and protect boreholes and water abstraction areas, whether the water source is surface water or groundwater, as is the case in Denmark.

Wastewater management in a basin perspective

Basin-wide cooperation on managing and treating wastewater from all polluters such as households, industries and agriculture is also important. It paves the way for the most efficient treatment solutions in a cost-efficient manner. It is important to ensure that wastewater is treated in the whole basin area. Otherwise, it may harm surface or marine waters near other cities and communities. If the treatment is inefficient, it will have severe consequences for the whole basin area and the environment, fisheries and bathing water quality. It will also become more expensive for water consumers to clean up the environment after the damage is done.

Adapting to a changing climate in and outside of the city

Climate change has an impact on nearly all cities as many can look forward to more extreme weather events in the future. Cities will experience more heavy rainfalls and/or flooding from rivers and streams or rising sea levels and storm surges. Activities in the open land outside the city will have an enormous impact on how the city will be affected by flooding. It may be wiser to manage heavy rain on farmland than by flooding cellars in residential areas. Nature Based Solutions allow local drainage of rainwater and may offer better room for water storage in rivers and streams than concrete canals and paved areas.

Enabling trust and joint decision making

Aligning basin management with the development of liveable cities depend on a strong cooperation between all basin stakeholders. A common vision combined with trust, reliable water resource information, planning tools and digital solutions enable joint decision making across different stakeholders in the basin.

For Denmark, basin-wide approaches is related to the demands from the EU Water Framework Directive calling for adoption of River Basin Management Plans in EU-countries and for transboundary basin areas. Accordingly, Denmark has been distributed into one international and three national river basin districts.

Furthermore, the UN Sustainable Development Goals state that all countries have to implement calls for integrated and basin-wide approaches to water management. It even has a dedicated target (SDG 6.5) which aims to implement integrated water resources management at all levels by 2030, including through transboundary cooperation as appropriate.

A basin connected approach to sustainable groundwater abstraction, Greater Copenhagen Area, Denmark

As in the rest of Denmark, the production of drinking water for the greater Copenhagen area is based solely on groundwater. The abstraction of approx. 55 mio. m^3/year takes place from 54 well fields located across 21 municipalities. Consequently, the water supply to the Greater Copenhagen area depends on a close and trustful collaboration between the water utility and these basin connected municipalities in terms of licensing and groundwater protection. Behind the licenses to abstract groundwater lies years of negotiation and joint planning between HOFOR (Greater Copenhagen Water utility) and the municipalities. Through the water tariff, the consumers in the Greater Copenhagen area finance groundwater protection measures such as afforestation, regulation of the use of pesticides and information campaigns. To a certain extent, groundwater abstraction affects surface ecosystems, water flow in streams and the groundwater quality. A sustainable abstraction of groundwater is thus important to reduce these impacts. At the same time, consumers expect a stable and safe supply of drinking water. HOFOR therefore carries out comprehensive monitoring and risk assessment in close dialogue with the municipalities to secure a stable, healthy and sustainable supply.

(Courtesy: HOFOR – Greater Copenhagen Utility and the municipalities of Copenhagen, Albertslund, Brøndby, Dragør, Furesø, Glostrup, Hvidovre, Rødovre, Ishøj, Køge, Ringsted, Lejre, Hillerød, Roskilde, Egedal, Greve, Høje Taastrup, Frederikssund, Ballerup, Gladsaxe and Solrød as well as The Danish Environmental Protection Agency)

Photo credit: Flemming Jeppesen, Fokus

Increasing flooding calls for immediate cross-municipal cooperation, Central Denmark Region, Denmark

With its 160 km, Gudenåen is the longest river in Denmark and runs through seven municipalities. Climate change has led to an increase in precipitation and flooding which calls for increased cross-municipal cooperation in order to create holistic, long-term solutions. This includes engaging with a diverse set of stakeholders ranging from landowners to museums to help identify challenges and create new climate adaptation solutions. A hydrological model and warning system covering all 160 km's has been developed in order to inform stakeholders and produce future climate adaptation scenarios. Furthermore, a mapping of the local stakeholders, their interests and objectives has been carried out. The purpose of this was to involve stakeholders and get an overview of their experiences with flooding and possible solutions. This is important as future climate adaptation solutions should not only aim to reduce flooding but also create a common understanding of the river system as one system and develop climate adaptation solutions which resonate with the local stakeholders. The aim has been to create more holistic solutions with added value for the various stakeholders along Gudenåen.

(Courtesy: The Municipalities of Hedensted, Horsens, Skanderborg, Silkeborg, Viborg, Favrskov and Randers as well as Skanderborg Water Utility and the C2C CC Secretariat, DHI, Niras and Orbicon)

7. DIGITAL TRANSFORMATION OF URBAN WATER MANAGEMENT

Digitisation and digitalisation can transform the water sector

The water sector has changed a lot since the creation of the world's first Ministry of the Environment in Denmark in 1973. But a new transformation is on the way - the digital transformation.

The water sector is old and operates with long-term planning and investment horizons - but as an industry, it is young and change is on the way. With proper attention to cultural change, full-cost recovery business models for water utilities and increased attention to educating more young water professionals to become technical experts and leaders of the future, digitalisation may contribute to the needed change and also connect the water sector better to the broader smart cities agenda and increased citizen involvement.

A digital water vision for 2030 could be that large efficiency gains can been attained, while it can also become possible to cut across specialist, organisational and regulatory silos and thus achieve more holistic, whole-water-cycle based and value-creating water sector management. Achieving the UN Sustainable Development Goals through digitalisation is an obvious driver that can potentially contribute to making the water sector more efficient, more innovative, less fragmented and better at supporting liveability as well as promote trust and transparency in governance.

Digitisation, digitalisation and digital transformation in Denmark

Denmark is among the most digital countries in the EU and the world – and a citizen's contact with the public sector is today digital by default. 94% of the population now has Internet access at home and digital mail is used by all households.

A key example of digitisation in the water sector is the Danish Digital Elevation Model (DEM), which consists of data sets developed from airborne laser scanning of the country. The data is processed to provide the elevation conditions of the landscape with a high degree of detail and great accuracy, currently in a 0.4 m grid for the entire country. The data is freely available and used e.g. for flood modelling and climate adaptation planning services by municipalities, utilities and private companies. New methods for monitoring the water cycle are also rapidly emerging, including the use of satellites, drones, autonomous vehicles, as well as in situ sensors and passive samplers.

A key example of digitalisation is within household metering of water consumption: In the 1980s, mechanical meters were installed across the country. These are now being replaced by IoT enabled smart meters. These can be read remotely for billing purposes, be used to detect consumption patterns and distribution pipe leakage as well as predict wastewater flows across the sewer network.

Another key example is wastewater treatment plants, which were subject to instrumentation, control and automation in the 1990s. This is currently taken to the next level by introducing e.g. on-line N_2O-sensors and adaptive model-predictive control algorithms that can limit greenhouse gas emissions and link the plant's energy consumption and production patterns to the electrical smart grid and provide flexibility needed to balance the renewable and weather-dependant wind and solar energy sources. New data-driven analysis and control algorithms are also spreading based on deterministic model understanding, statistical descriptions of uncertain data sources as well as machine learning and artificial intelligence aimed at exploiting the growing volumes of data of varying type, quality, and frequency.

Finally, digital transformation is about people and organisations - on top of the technical digitisation and digitalisation efforts. For example, the Danish water utility Aarhus Vand states in its digital strategy that it aims to empower employees by providing access to systems, data, knowledge and colleagues anytime, anywhere. Furthermore, increased accessibility and overview of data and information is expected to enhance knowledge exchange, collaboration, innovation and partnerships and indirectly transform the organisation while making it a more attractive and productive workplace.

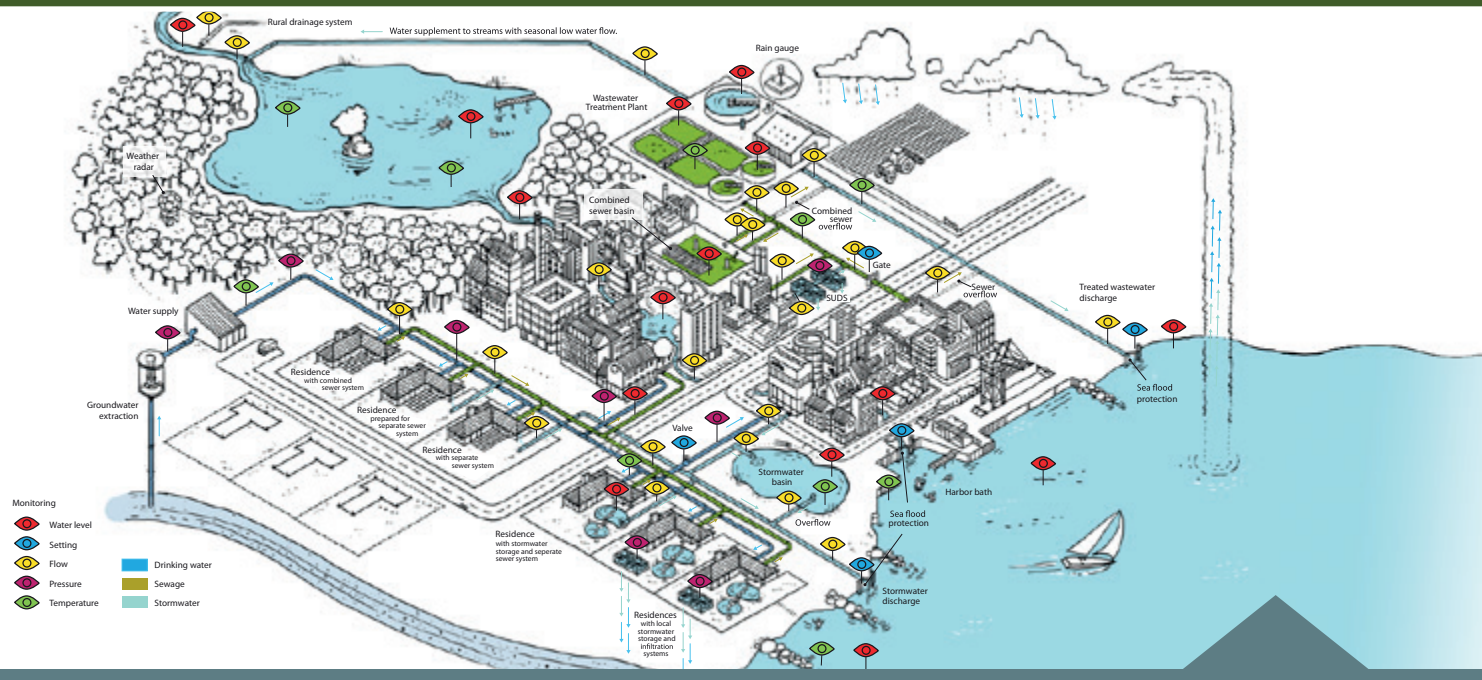
International cooperation on digital transformation

The IWA Digital Water Programme is a gateway for water utilities to access global knowledge on the application of digital approaches to improve capacity and performance. The programme serves (1) as a starting point to initiate the dialogue on digital water, (2) as a mechanism to learn new ideas and to build own experiences in applying digital solutions, and (3) as a platform to share and discuss experiences on digital transformation, see www.iwa-network.org/programs/digital-water

Real-time combined optimisation of the sewer network and wastewater treatment plants, Kolding, Denmark

The public wastewater utility BlueKolding wanted to exploit the optimisation potential through an intelligent use of real-time data from its entire wastewater system (i.e. both the sewer network and the wastewater treatment plants). Since its implementation, the advanced algorithms of AQUAVISTA™ Plant have reduced overflows from the combined sewer network by 83 percent, increased the hydraulic capacity of the wastewater system by 80 percent and reduced nitrogen discharge by 27 percent. Operating expenses have been lowered thanks to a reduction in the use of chemicals and energy by 46 and 23 percent, respectively. A new add-on is the 'BlueGrid' project, which uses rainfall forecasts from weather radars and numerical weather prediction models along with model predictive control and artificial intelligence (AI) in the AQUAVISTA™ Plant SMARTGrid platform to provide balancing to the demand-response electricity market. The power consumption is furthermore planned and carried out in conjunction with the spot market electricity price fluctuations 24 hours ahead. This makes BlueKolding a flexible consumer of renewable wind and solar energy, which saves energy costs, reduces its climate footprint and supports the UN SDGs.

(Courtesy: BlueKolding A/S, Krüger A/S and Technical University of Denmark)



Accelerating business transformation through a utility-wide digitalisation strategy, Aarhus, Denmark

Aarhus Vand – the water utility servicing Denmark's second-largest city – is full steam ahead with implementation of a digital transformation strategy which sets an ambitious direction that will accelerate and increase its focus on continued innovation of digital solutions and transformation of the utility's business. Accessibility of data, information and knowledge which promotes sharing, cooperation, innovation and partnerships is at the core of Aarhus Vand's business and digital strategies. Aarhus Vand is using data driven approaches that include use of real time data, advanced analytics, optimisation and decision support to operate its WWTPs to reduce energy consumption and produce enough energy to become net producers of energy and thereby defer capital costs while meeting environmental regulations. The same data-driven approaches and technologies are used to optimise the water supply systems to reduce NRW and energy consumption, ensure high water quality and operate the systems efficiently and sustainably. Aarhus Vand is currently starting a project to build the world's most resource efficient WWTP 'ReWater' and has chartered a Digital BluePrint, which outlines how the utility wants to work with data and new IT technologies to innovate, design and operate the new resource recovery plant.

(Courtesy: Aarhus Vand)

8. URBAN WATER GOVERNANCE

A response to social and environmental challenges in cities

New technologies and innovative solutions go hand-in-hand with regulation and organisational development - from the large cholera outbreak in 1853 with more than 7,000 dead in Copenhagen to modern, efficient and stable water supply and sanitation facilities.

Successful water management requires strong governance structures. In Denmark, two ministries are primarily responsible for regulating the water sector: The Ministry of Environment is responsible for the environmental regulation and The Ministry of Climate, Energy and Utilities is responsible for the economic regulation. At the local level, 98 municipalities serve as water authorities, responsible for local water plans and compliance with legislation and for issuing permits to water utilities. Being a member of the European Union, compliance with EU directives such as the Urban Wastewater Treatment Directive, the Drinking Water Directive and the Water Framework Directive guides legislation. The Danish Water Sector Act states that water utilities must be efficient and have low and stable prices. They must furthermore ensure a stable supply of high quality water with respect to public health and environment and with due consideration to climate and nature.

Organising the water sector
The Danish water sector is very decentralised. All wastewater utilities and larger water utilities are owned by municipalities. In addition, there are approx. 2,500 small consumer owned waterworks. The average water utility is responsible for drinking water supply, wastewater collection and treatment, stormwater management and water related climate change adaptation activities. All cities in Denmark have climate change adaptation plans and utilities play an important role in the implementation of stormwater solutions.

Securing sufficient funding
Securing funds for service delivery and investments is a challenge for water managers in most countries. In Denmark, municipally owned utilities are organised as limited companies governed by a board established by the municipality but are still economically independent. They are not-for-profit and operate under a break-even principle based on full cost recovery. Within a price-cap, set by a national regulator, all costs for running the utility must be covered by water and wastewater consumer tariffs. Utilities cannot be subsidised and likewise, the utility's funds cannot be used for other purposes than daily operations, necessary investments, innovation and contributions to the overall development of utilities and the water sector.

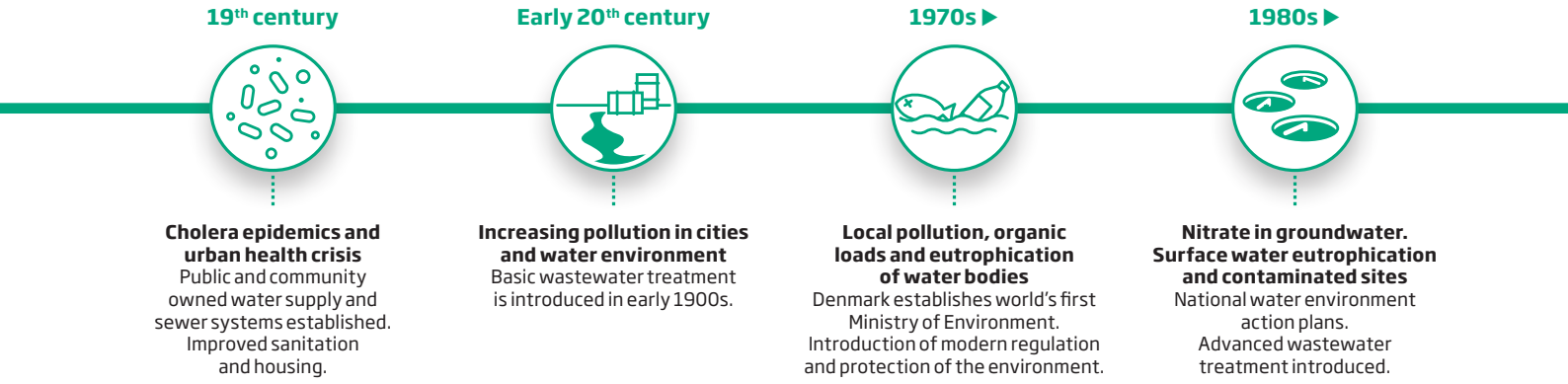
The average water price in Denmark is approx. EUR 9 per m^3. Two-thirds of this covers collection and treatment of wastewater (and related taxes) and one-third covers drinking water supply (and related taxes).

Water consumption is closely related to the price
In 2019, the average Dane only consumed 101 litres per day. This has decreased by 40 percent since 1980 due to a combination of economic incentives to save water and general environmental awareness. Although the Danish water price might seem high, the average household spends less than 1.5 percent of their household budget on water and wastewater, well below the UN recommendation on affordable water, which sets the limit at 3 percent. While water prices may have increased, household expenditure for water and wastewater has been stable in recent years because of lower consumption patterns.

Involving the local community
Active citizen involvement is key to smart, liveable cities. Experience from Denmark and other countries show that water projects are more likely to become successful when citizens take active part in their development, planning and implementation.

Identifying all relevant stakeholders and embracing them in the dialogue on urban development is crucial. This is also why the IWA Principles for Water Wise Cities include a call for 'water-wise communities' and transdisciplinary cooperation.

Water governance in Denmark - a historic overview



Restructuring a broken revenue chain to sustain reliable service provision, Johannesburg, South Africa.
Emfulini Local Municipality south of Johannesburg in South Africa receives a yearly water bill of EUR 8 million from the bulk water provider Rand Water but only manages to collect EUR 400,000 from consumers. Consequently, water distribution and wastewater infrastructure is falling apart and the municipal debt is building up. Controlling the level of non-revenue water and achieving full cost recovery is crucial for any water authority. In South Africa, however, the challenges are not only technical but also socio-economic with a huge indigent segment of the population with limited ability, and unfortunately also limited willingness, to pay for water with reference to the constitutional right to water and the 'free basic water for all' policy. This has made it difficult to make consumers aware and accept that every drop of water comes at a price and that with no revenues, the taps will stop running. The government-supported South African - Danish Strategic Water Sector Cooperation has focused on restructuring the revenue chain both at the national and municipal level. The programme has worked with the South African Water Ministry on the policy for financing and tariff setting and is working in a number of municipalities on full cost recovery by applying the Danish revenue cap model.

(Courtesy: Danish Environmental Protection Agency and Embassy of Denmark - Pretoria)

1990s ▶

Focus on energy consumption and water loss. Pesticides in groundwater. Need for improved removal of nutrients
Increased action to minimise water loss.
Rehabilitation of water supply and sewer networks.
Automation.
Implementation of EU water directives.

2000s ▶

Calls for increased urban liveability. Pollution of surface and groundwater
Mapping and monitoring of groundwater.
EU Water Framework Directive.
Wastewater treatment improved.
First harbour baths open.
Water utilities become independent, municipally owned entities.

2010s ▶

Climate change and urban flooding. Resource scarcity. Emerging contaminants and microplastics
Mandatory municipal climate change adaptation plans.
Economic and performance benchmarking for utilities, focus on efficiency.
UN SDGs adopted.

2020s ▶

Focus on efficiency and digitalisation. Climate, biodiversity and resource crisis. Pesticides and emerging contaminants.
Action plan for energy and climate neutral water sector by 2030.
Implementation of SDG's.
New legislation on climate change adaptation.
CSO reduction.
Resource recovery.
Groundwater protection.
Digital transformation.

9. INNOVATION & PARTNERSHIPS

The Sustainable Development Goals can only be met if we work together

Working together in partnerships when developing water solutions for smart and liveable cities may lead to more innovative and efficient solutions. This improves the framework for innovation, exports and prosperity.

Partnerships increase innovation
A partnership on 'Water for Smart Liveable Cities' can be any collaboration undertaken jointly by multiple parties such as government institutions, municipalities, water utilities, private companies (e.g. consulting engineers, architects and/or technology providers), universities and research institutions, trade associations or even private citizens.

As highlighted in 'SDG 17 – Partnerships for the Goals', including different perspectives promote a closer dialogue and collaboration which can also create synergies to existing projects. The result is often better, and more innovative and efficient solutions. Smaller companies involved can benefit from gaining access to knowledge, networks and technologies available in the partnership and in return contribute with their specialised knowledge.

Innovation in partnerships creates significant results in the water sector
Innovation in technologies and processes is necessary to meet expectations from both customers and authorities. It is important to secure water for people in both cities and rural areas and to secure good water quality for surface and marine waters. Being able to swim in the harbour of cities like Copenhagen and Aarhus is only possible because of a very innovative water sector.

Multi-stakeholder partnerships have created significant results in the water sector: They have lowered urban water loss, improved wastewater treatment, urban drainage and bathing water quality and increased recovery of energy and other resources on the road to a climate neutral water sector – to name a few important achievements contributing to smart, liveable cities.

A strong DNA for Danish water-partnerships
Water utilities play an important role in the innovation of the Danish water sector. Because of the ownership structure and the not-for-profit model, water utilities often engage in innovation projects and are happy to share results with colleagues in other utilities, including voluntary benchmarking on economic and environmental performance. Utilities function as test beds for innovation and provide opportunities for piloting new ideas from the partnerships in which they participate. In doing so, they support and stimulate the development of innovative products which are essential for development of both the smart and liveable city.

Public funding encourages partnerships
Public funding may encourage partnerships and lower the economic risk associated with research, development and demonstration of new, advanced technology. In Denmark, various funding programmes (incl. the Eco-Innovation Programme (MUDP) under the Ministry of Environment, the Water Sector Development and Demonstration Programme (VUDP) and Innovation Fund Denmark) encourage businesses to join strategic partnerships when they apply for co-financing of innovation projects and testbeds and ensures swift implementation of the projects.

Water Vision 2025
In 2015, all the key stakeholders of the Danish water sector developed a joint national vision for the future development of the sector. The main objective of 'Water Vision Denmark' is for Denmark to become a global leader in providing intelligent, sustainable and efficient water solutions. To meet this goal, Denmark must increase innovation and expand its position as a growth centre for smart water solutions. The ambition is to double the export of water technology and create 4,000 new jobs in the industry. By sharing knowledge and technologies, Denmark also contributes to the global implementation of the UN Sustainable Development Goals.

Photo credit: Hans Søndergaard

Unique water partnership to stop global water loss through system integration and holistic monitoring, Denmark

Clean drinking water is a scarce and valuable resource under increasing stress. Unfortunately, water losses are high in many countries around the globe. Water losses in Danish drinking water systems are among the lowest worldwide, with an average loss below 10 percent. The LEAKman project was initiated to demonstrate Danish water solutions and pave the way for new technologies. The partnership consists of nine different partners (companies, utilities and research institutions), and a unique feature about LEAKman is that the partners work collectively to deliver one single holistic Non-Revenue Water Management System. By combining several smart systems with seamless integration and holistic monitoring, LEAKman connects the entire water distribution network. The result is one solution that facilitates water loss reduction to less than 20 percent for any system within just a few years – with possible reductions to below 10 percent. Two large-scale demonstration facilities have been established near Copenhagen, Denmark. In these areas, a combination of pressure reduction, online hydraulic modelling, water balance reporting on DMAs, and noise loggers listening for leakages has reduced leakage levels to a sustainable minimum.

(Courtesy: LEAKman partners: AVEVA, AVK, Technical University of Denmark, Grundfos, HOFOR – Greater Copenhagen Utility, Kamstrup, Leif Koch, NIRAS and Novafos)

Climate Tile – a green and scalable climate adaption system for dense cities

Climate change is pushing the boundaries in our cities. The Climate Tile is a scalable climate adaptation tool which rethinks sidewalks as water management systems. The main component is essentially a hybrid between a concrete tile, an intelligent water pipe system and a permeable surface. The tile's purpose is to positively answer the climate change challenges whilst creating new adventures and green, urban spaces in cities. The Climate Tile can catch and redirect 30 percent of the extra rainwater projected to come due to climate change and thereby prevent overflows from the existing drainage infrastructure. In addition to this, it also brings other qualities into play as it allows for watering of trees and plants, spaces for stay and a more beautiful surface. The water contributes to the growth of an urban nature and an improved microclimate which benefits local citizens as it contributes to making the city both a healthier and more attractive place to live. The scaling potential of the product is comprehensive – for example New York City has 20,000 km of sidewalks.

(Courtesy: TREDJE NATUR, IBF and ACO Nordic with financial support from Realdania and The Market Development Fund)

Photo credit: Andy Hoang, DINES JØRGENSEN & CO A/S

Rockflow - an innovative and natural solution for sustaining water resilience

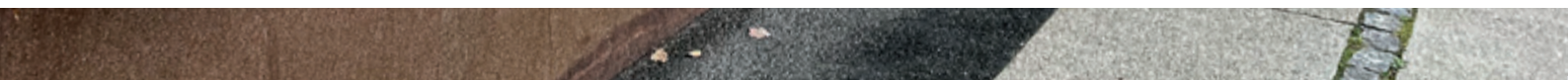
Climate change is causing more and more heavy rainfall. Especially in urban areas, stormwater causes streets to flood with water more frequently. The main reason for this is the insufficient capacity of the existing sewerage system to transport the water. Rockflow is an innovative water management system that buffers the stormwater quickly and effectively. Depending on the local legislation and situation, the water is either infiltrated into the soil or gradually discharged to the sewer system or to a suitable surface water body. This solution, made of natural stone wool, prevents flooding and helps to restore the natural water balance in urban areas. The Rockflow elements can absorb up to 95 percent of their volume in water without losing form or strength which makes them suitable to be placed under streets and squares. At the end of their life span, the elements can be fully recycled in one of the ROCKWOOL factories into new stone wool products.

(Courtesy: ROCKWOOL Group, GEO, Dines Jørgensen & co A/S, C. Hobøll & Sønner and CALL Copenhagen)

Green Climate Screen

Many cities struggle with traffic noise and recurring flooding during heavy rain. A new 'green screen' has been developed to tackle both issues as well as offer architectural qualities by handling rainwater run-off in vertical evaporation elements. The primary hydrologic mechanism is evaporation so its carbon footprint is low and space requirements and CO_2-onerous soil disposals are reduced. It prevents pollution of the aquatic environment and issues with high groundwater levels are avoided. With its multifunctional design, it also contributes to noise reduction, improved air quality, heat island mitigation, enhanced habitat quality and urban space activation. The concept was first demonstrated in 2019 with a modular solution in a neighbourhood next to one of Copenhagen's busiest roads with 45,000 vehicles per day. Here, a 80 m long and 3 m high screen receives rainwater run-off from 240 m^2 roof surface. It is dimensioned to handle a 10-year rainfall event – the same as the public sewerage system. The introduction of vertical elements for handling rainwater run-off opens up a new type of green city structures.

(Courtesy: Malmos A/S, Aarsleff A/S, TL-Engineering, Niels Lützen Landscape, 3B, AC-Steel, PileByg, Danish Technological Institute and University of Copenhagen)



10. THE TRUE VALUE OF WATER

A Danish perspective on how we can shape our water future

In Denmark, we value our water. We care for how we extract it, use it and release it back to nature. We consider water a valuable resource in the circular economy and a contribution to reaching our green energy and climate goals. Above all, we value water for its potential to improve lives.

Let's protect our drinking water
Everyone deserves water that is clean and safe to drink. In Denmark, our drinking water origins entirely from groundwater. Our strategy is to protect our groundwater resources and in return, our drinking water only receives minimal treatment. Most waterworks simply pump, filtrate and distribute it to the consumers. We monitor it carefully and work to secure clean groundwater for future generations as well.

Let's care for every drop
Water is a scarce resource – and every drop counts. We must make the most of the water we have. In Denmark, we have a low water consumption. The average Dane consumes just over 100 liters a day, our water loss is less than 8 per cent and our industries are increasingly focusing on water efficiency and reuse in their production. The price is based on full cost recovery, which ensures a reliable and efficient water supply 24 hours a day. Now let's fight to make every drop count worldwide.

Let's use our wastewater as a resource
Wastewater should no longer be thought of merely as a problem. Instead, let's turn our wastewater treatment plants into energy and resource recovery facilities where we can extract phosphorous and produce organic fertilizer and biogas. In Denmark, we also aim to utilise wastewater even further up the value chain to produce products such as biofuels and bioplastics.

Let's move towards an energy and climate neutral water cycle
Water plays a key role in creating a sustainable world. It is important to make sure our water management is sustainable as well. In Denmark, we use a minimum of energy to pump and treat water. We continuously work to be energy efficient and we contribute to a greener and more flexible energy system by producing energy from wastewater. In fact, some facilities are now producing more electricity than they consume. By 2030, the Danish water sector aims to be energy and climate neutral across the entire water cycle.

Let's use rainwater to create resilient and liveable cities
Rainwater can improve urban life if it is managed wisely. In Denmark, we store and delay rainwater and stormwater in parks, streets and football fields to create both resilient and liveable cities for a growing population. By doing so, we adapt to the changing climate and weather patterns as well as increase our biodiversity. So, while we may not be fans of rainy days, we appreciate what rainwater can do for us.

Let's swim in our city harbours
Water can be used actively in urban development. Waterfront areas and blue-green infrastructure can transform neighbourhoods and create economic growth. By treating our wastewater and managing our stormwater in underground basins, we have transformed polluted inner-city harbours into urban oases. So when the weather permits, you can go fishing or swimming in the harbour in Danish cities.

Let's collaborate and solve the global water challenges
We want to connect, inspire and learn from each other in global partnerships – and work together to contribute to a sustainable world. Water is one of our most valuable resources and it plays into many other agendas like adapting to and mitigating climate change and increasing biodiversity. Through national and global partnerships across sectors, we can deliver on the UN Sustainable Development Goals on water and sanitation, affordable and clean energy, sustainable cities and communities and life on land and under water.

Water is **life**. And with the right care for water, we can make better lives.

The partners behind Water Vision Denmark aim to further innovation in the Danish water sector, increase Danish export of water technologies to the world and contribute to job creation across the water sector.

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