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WATER INFRASTRUCTURE

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FRONT PAGE PHOTO

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CHAPTER 1

A successful programme for reducing NRW

Achieving an efficient NRW reduction through a holistic approach

Several aspects - covering the initial planning phase to the day-to-day operations, the use of high quality installations, good workmanship and introduction of new technology - need to be addressed in order to reach low NRW levels and ensure long-term success.

Achieving and maintaining an NRW level close to the Economic Level of Leakage (ELL), based on cost-benefit calculations of operating costs, strategy and activities, requires a strong and continuous focus on planning, operations, infrastructure maintenance, workmanship and performance monitoring. A Management Information System (MIS) has to be established to continuously monitor the performance of the operation and evaluate the effects of the implemented programme. The more information and data that is available from the water distribution system and the more integrated the MIS is, the more accurate the performance indicators will be. This will allow better decisions to be taken regarding new invest-ments.

A strong MIS can therefore be the key to success in terms of prioritising actions and securing a fast return on investments. It is very important that an NRW management and water loss control programme is established and understood from the highest level of the organisation to the lowest. NRW reduction must be an agreed strategy for the entire organisation based on a holistic NRW master plan. Capacity building of staff at all levels in the utility, and its contractors, is therefore a vital element in the early phase of an NRW reduction programme.

High-quality products pay off in the long term
As improvements in the water distribution infrastructure need to last for a long period of time, it is highly recommended to base the selection on life cycle costs analysis and use of high-quality components and products. Aspects which should be considered when selecting, purchasing and in-stalling new components include the length and the scope of the warranty, Total Cost of Ownership, energy con-

The ILI indicates the severity of the NRW issue and can also help determine the level of action.

ILI	Severity	Action
< 2	Very low/low	No intervention required, typically not economically viable
2 – 4	Medium	Monitor the area closely and prepare for intervention
4 – 8	High	Intervention to be planned and scheduled
> 8	Very high	Immediate intervention required

sumption as well as their accuracy and long-term reliability. The different aspects of successfully reducing and maintaining a low NRW level are described further in the following chapters.

Using the right KPIs for NRW
NRW is commonly indicated and reported in high-level reporting as a percentage of system inputs into the system. This approach is acceptable for NRW levels above 20 per cent, as the NRW will be high no matter how it is measured. However, many factors can affect this performance Indicator (PI) so it does not give an accurate picture of system performance. For the water utility staff charged with implementing NRW reducing strategies and activities, the NRW and leakage levels should be reported in both cubic metres/km of pipe/day and cubic meters/connection/day. The International Water Association (IWA) has further defined the Infrastructure Leakage Index (ILI), which reports real losses against expected unavoidable water losses for the system. This is calculated by taking into account the service pressure, the number of connections and the length of the pipeline. By using these additional performance indicators, the utility can target NRW reducing activities far more effectively to the physical areas and water balance components with the shortest and highest payback.

Example:
Consider two different systems, a rural and an urban, where the rural system has three times more pipeline length than the urban system, but the number of customers is the same, the consumptions are identical, and the system inputs are identical. The leakage percentage will be the same. However, the urban system will have three times higher leakage per km of pipeline, making leak detection far more effective in the urban system, with faster payback times than the rural system, and thus performing far worse than the rural system.

Implementing comprehensive NRW reduction plan, State of Johor, Malaysia

Ranhill SAJ is supplying water to a population of around 3.9 million. The annual billed water consumption is approximately 475 million m^3 and NRW approximately 24 per cent. Ranhill SAJ have successfully reduced NRW from 47 per cent to 24 per cent through dedicated leakage control and now the target is to reduce NRW to 5 per cent by the end of 2025.

The Johor NRW Reduction Project includes a comprehensive pipe rehabilita-tion and replacement programme, combined with leakage detection, pressure management, meter replacement and automatic meter reading, GIS update, hydraulic network modelling, and establishment of a SCADA system as well as a Management Information System. The total budget is MYR 4.17 billion, approx. EUR 876 million.

The first completed DMA included 6.3 km of main pipes and 529 service connections. Half of all main pipes and service connections were replaced with a fully welded HDPE system. After the replacements, NRW was below 5 per cent and in zones with full replacement, there were no leakages detected.

CONTRIBUTORS

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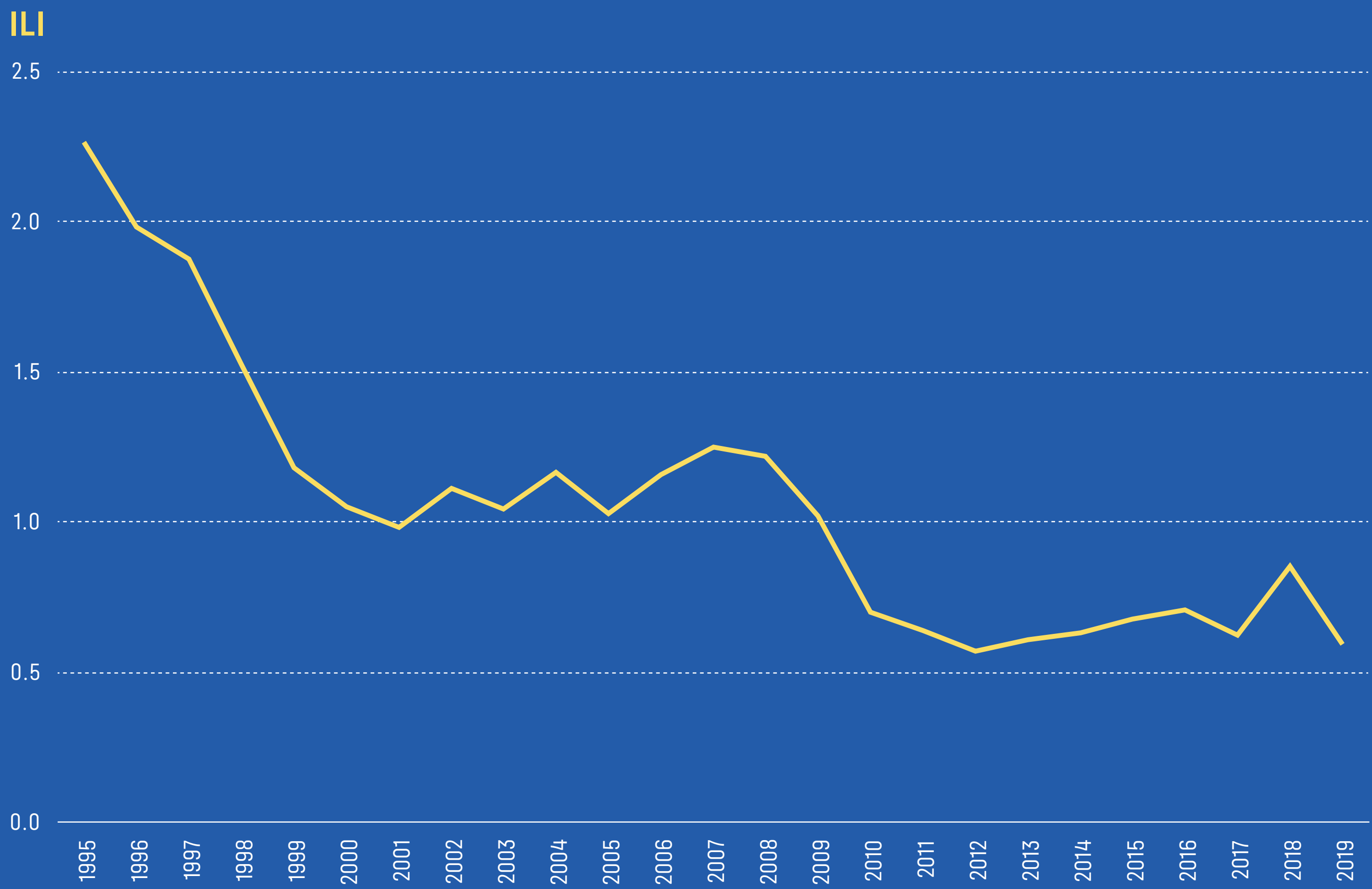

Dedicated network and system efforts lead to impressive NRW results, Odense, Denmark

In the city of Odense, the hometown of renowned Danish fairy tale writer Hans Christian Andersen – water utility VCS Denmark has been supplying the city with clean drinking water since 1853. VCS Denmark operates seven waterworks, eight wastewater treatment plants and 3,400 km of pipeline networks.

Since 1993, VCS Denmark have carried out a district zoning of the pipeline network. The branch network is now operated with 63 DMAs, supervised by the SCADA system, covering more than 95 per cent of the supply network. This enables optimal operation and leakage detection. In addition, a pipe rehabilitation program has been performed over a 10-year period, reducing burst frequency by 50 per cent. In 2019, VCS Denmark obtained a NRW level of 5.3 per cent, water losses of 1.22 m^3/km/day and ILI at 0.60.

Today, low leakage levels and a secure water distribution is performed with aid from smart meters, active online leakage control in the DMAs and a management decision support system. Every five minutes, the SCADA supervised network calculates the optimal pressure and flow, based on data from online values in the DMAs and five booster stations. In that way, the loss is kept to a minimum.

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VCS Denmark

CHAPTER 2

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 pro-tection 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 drink-ing 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 disin-

fection. The groundwater I 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 reduc-ing carbon emissions globally. Biological rapid sand filters – which have been used, refined and optimised in Denmark for decades – are now receiv-ing 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 per-cent.

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 acces-sible. This transparency has migrated into development of advanced drinking water databases with information on e.g. water quality, daily opera-tional 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 ex-pected 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.

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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 balanc-es 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.

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CHAPTER 3

Stormwater management for resilient and liveable cities

Creating resilient and liveable cities through stormwater and cloudburst man-agement

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.

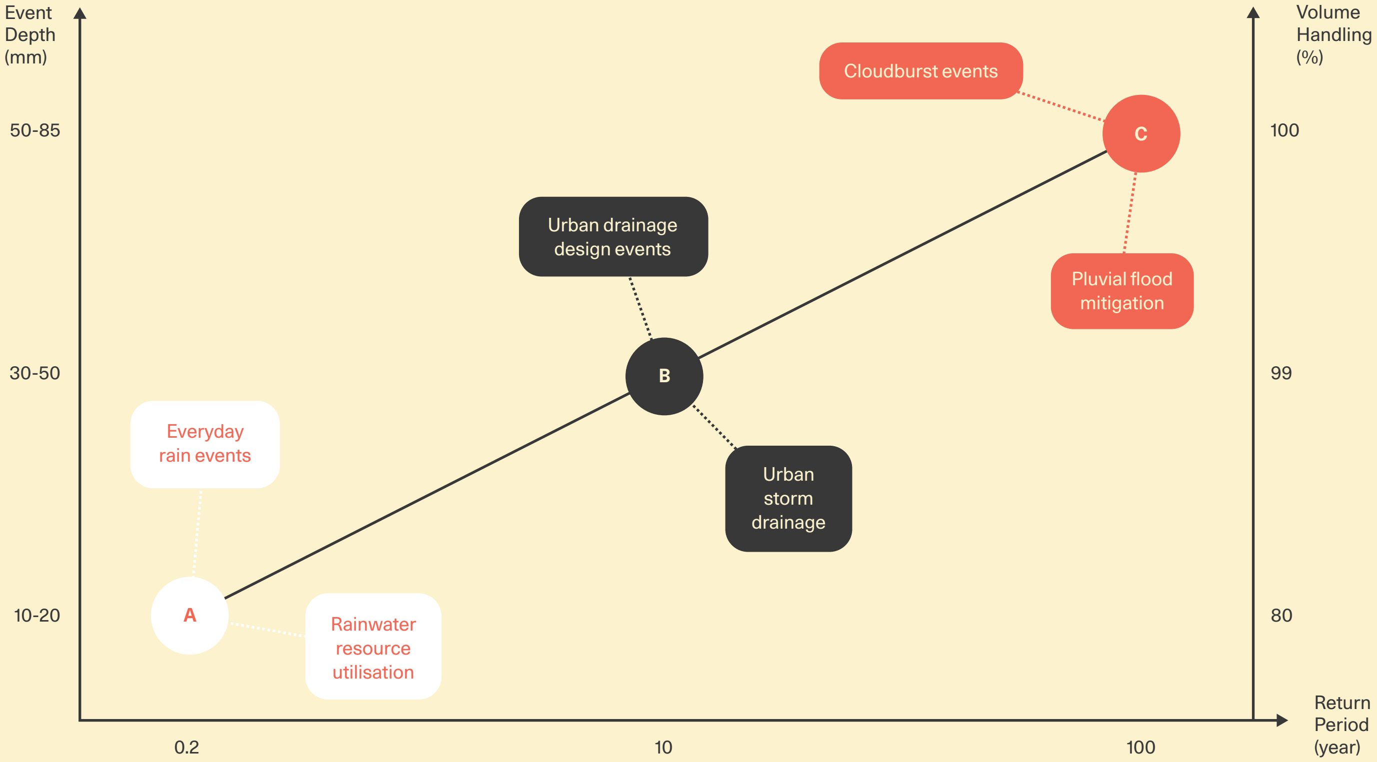
General principles of water infrastructure in the liveable city

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 utilization considering 'everyday rain events', (B) urban storm drainage considering 'design events', and (C) pluvial flood mitigation considering 'cloud-burst 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 net-works (combined or separate sewers). These are now increasingly being supplemented by Nature Based Solutions (NBS) above ground, which pro-vide amenity value and are combined with the traditional sewer systems to create smart water solutions, which also contrib-ute to more attractive urban spaces for local citizens.

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).

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 cloud-burst 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 emergen-cy 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 plan-ning 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 transfor-mation is already well underway in Copenhagen and in many other Danish cities.

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, in-creases 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 m² area and together with a surface basin in the park, it forms a storage facility of 1,850 m³. 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 m³ of rainwater on the surface with an iconic 80 metres long concrete wall formed as the Fibonacci spiral for the neighbouring schools to practice 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.

CONTRIBUTORS

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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 under-ground 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.

CONTRIBUTORS

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CHAPTER 4

Creating resilient and liveable cities with nature-based solutions

Adapting to a changing climate with more frequent and more intense rain events also presents an opportunity to rethink urban development and gain greater value from investments. By maintaining a holistic view, the incorporation of various nature-based solutions can contribute to greener and more pleasant urban spaces with added benefits for the city residents.

Just a few decades ago, most cities in Denmark regarded rainwater as something to dispose of and hide in sewers – not as the valuable resource it actually is. Today the situation is quite different, as water is now recognised as an asset with enormous potential to enhance the daily lives of city dwellers. This also makes investments in climate change adaptation projects easier to justify to the public. While choosing an integrated approach may initially be more complex, as it involves a broad range of environmental, economic, and social strategies, it is often more cost-efficient from an overall societal perspective.

Creating the liveable city

While there is no global definition of what makes a city 'liveable', various international rankings of the world's most liveable cities typically consider factors related to dimensions such as safety, healthcare, economic and educational resources, infrastructure, culture, and environment. The best cities manage to create synergies between these dimensions. When nature-based solutions (NbS) are designed correctly, they can serve multiple functions beyond rainwater management and thereby play a key role in creating 'the liveable city'. This is also in line with the International Water Association's 'Principles for Water-Wise Cities' which among other things focus on Water Sensitive Urban Design that not only reduces the risk of flooding, but also enhances liveability though the presence of 'visible water' in urban design.

The key is long-term planning, as many projects are built to last for decades, or even longer. When deciding upon which projects to implement, city planners and other decision makers need to consider what kind of city they want to have in fifty years from now, as decisions made today will have a significant impact on the city's urban structure for years to come. At the same time, there is a dawning understanding that the existing, expert-based service and the passive citizen role is no longer adequate. Broad stakeholder collaboration and involvement is needed. When creating liveable cities, three consecutive challenges need to be addressed:

- **How do we create climate-resilient societies in practice and utilise the potentials to strengthen the sustainable transformation of urban and rural areas?**

- **How do we develop new types of interaction with the citizens?**

- **How can we work innovatively with climate adaption and develop new professional skills and approaches to planning?**

Estimating the economic value of NbS by thinking of the multiple uses of rainwater, it is possible to create synergies from investments. In many cases, surface solutions with multiple functions are actually cheaper due to lower construction costs. However, assigning economic value to green or dual-purpose solutions and the positive spillover effects from these compared to traditional basins or sewerage system expansions can sometimes be difficult.

In Denmark, there are no national guidelines for calculating the benefits and added values of green solutions that involve NbS elements with multipurpose functions. However, two different tools have been developed for this purpose.

The first tool is a method for comparing expenses for building 'grey' vs. 'green' solutions. The calculations in this method include the various types of costs (such as project planning, construction work, maintenance etc.), the frequency of each cost, who the cost bearer is and if there are any associated risks. Finally, it also takes into account parameters such as the durability of the solution, the environmental effect(s), aesthetic and recreational aspects as well as possible synergies with other planned construction projects.

The second tool is called 'SPLASH' (in Danish: PLASK) and has been made available free of charge by the Danish Environmental Protection Agency to help calculate the socio-economic consequences of specific climate adaptation measures in a local area. SPLASH calculates the size of investments needed to guard against a given rain event and reveals the economic gains from each suggested action on a long-term basis (e.g., the reduced costs of flooding damages). The value of positive spillover effects such as increased green areas, reduced water consumption and increased CO_2 absorption etc. is also included. Both tools are available online (in Danish only) and can be used by Danish urban water managers to help them plan and prioritise their efforts.

Copenhagen's first climate resilient neighbourhood

An existing neighbourhood in Copenhagen has since 2013 under- gone a transformation to become more resilient to the effects of climate change such as strong and heavy rainfall. Once completed, the transformation will also result in green, beautiful urban spaces for the local residents to enjoy.

Principles
Unlike most of Copenhagen, the neighbourhood of Skt. Kjelds quarter in the North-Eastern part of the city is sitting on an incline, sloping down towards the harbour. Therefore, the main purpose is to retain surface water in the area and infiltrate as much rainwater to the groundwater as possible. Storage capacity is used during heavy rain and cloudbursts. During cloudbursts, the excess water is transported away from the neighbourhood to places where the risk of damage is minimised. The overall aim for the neighbourhood is to have flexible surface solutions that can manage daily rainfalls locally. During cloudbursts, surface solutions are combined with a conventional split rainwater sewer system,
ensuring a controlled transport of rainwater to the nearest harbour.

Taasinge Plads
The transformation of Taasinge Plads was completed in 2014. The area is now a green pocket park that demonstrates how to manage three different types of surface water fractions: Rainwaterfrom roofs, which is used for recreational use and play, rainwater from zero traffic areas, which is used for local infiltration and finally, surface water from roads, which is infiltrated through filter media. As salt is used as ice control in the winter, the road water does not infiltrate the groundwater, but is transported to the harbour. During cloudbursts, an integrated open storage capacity is taken in use and works as a blue element in the pocket park.

Bryggervangen and Skt. Kjelds Plads
Bryggervangen and Skt. Kjelds Plads was finished in 2019 and is a long stretch of road (34,900 m^2 and a roundabout), where green spaces, urban nature and linked surface water solutions have replaced asphalt and pavements. The applied urban nature is inspired by the characteristic wet/dry biotopes found in Copenhagen and uses their processes in a rational way to treat and retain rainwater. Surface water from roads is handled by first-flush solutions, which direct the polluted initial surface runoff (first flush) stemming from heavy rainfall to the existing sewer system, whereas the cleaner, 'second flush' is directed to green surface water solutions. This can be turned off in the winter to avoid salt intrusion into the green areas.

Both projects will be linked to the rest of the holistic system on the cloudburst branch, which will drain this specific area of Copenhagen.

CONTRIBUTORS

City of Copenhagen and HOFOR - Greater Copenhagen Water Utility. Strategic design advisors for the master plan of the area: THIRD NATURE. Advisors for Taasinge Plads: LYTT Architecture and WSP. Advisors for Bryggervangen & Skt. Kjelds Plads: SLA and NIRAS.

LOCATION

Copenhagen

CHAPTER 5

Managing rainwater with nature-based solutions

Nature-based solutions is the tool for climate change adaptation and increasing urban biodiversity, supporting a triple bottom line of planet, profit, and people, where the aim is to heighten urban resiliency.

Nature-based solutions (NbS) are measures that encapsulate the notion of water as a resource. At times, NbS are rainwater management, inspired by nature's methods such as permeable pavement and underground storage; at other times the solution is nature-based elements that support biodiversity.

Taking the pressure off the traditional sewerage system
Due to the large amount of impermeable surfaces present in cities, rainwater runoff in a city differs from the runoff pattern that occurs prior to the urbanisation process. The hyetograph below reveals that urbanisation has an impact. The runoff from a city covered with impermeable paving will result in quick and high runoff. As runoff from several catchments arrive at the same time to the same places in the sewers, it creates bottlenecks, heightening the risk of flooding.

By viewing NbS as an extension to the traditional sewerage system, the aim of NbS is to smoothen the runoff hyetograph and reduce pressure on the sewerage system. Runoff from catchments will arrive at the usual bottlenecks at different times. By delaying and reducing the maximum runoff, it is possible to reduce the risk of flooding.

Designing NbS to handle different types of rain events
In Denmark, there is no standard definition of how to design NbS. In practice, the recommendation is that every time you design a NbS, you need to consider everyday rain, design storms and cloudbursts (as illustrated in the 3-point approach method). Often professionals and stakeholders tend to focus on one type of rain event. However, there can be numerous problems in an area related to the different rain events. It is therefore highly important to focus on all types of rain events when designing solutions. NbS are particularly efficient for solving everyday rain challenges but when used carefully, NbS can contribute substantially to solving some of the problems associated with heavy rainfall and stormwater.

Testing NbS elements to meet international standards
When developing new or using existing climate adaptation products, there is often a need for full-scale testing, optimisation, and documentation of the product before implementation. The product might be subject to a European Standard and required to adhere to certain specifications. Or the producer might need to document the water balance of a new NbS element or the permeability of a specific pavement. Denmark has more than 30 years of experience with testing traditional components in sewerage systems and today it is also possible to test new climate adaptation products in a certified lab, where tests are run in a full-scale setup, using up to 30 l/s. Companies from other countries can also use the lab.

A tool for adapting to a changing climate
NbS, when strategically planned, represent a sustainable alternative of a storage/drainage facility compared to traditional rain and stormwater infrastructure. It is expected that more natural structures will drastically decrease the use of concrete structures and energy demanding technologies. Hence, integrating NbS into urban areas not only has the potential to solve climate change challenges, but also meet CO_2 emission reduction needs, mitigate heat islands, and increase biodiversity and public health via the creation of additional green areas in the city.

Examples of typical NbS elements

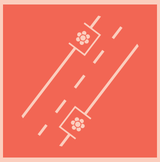
Clima ponds
To increase biodiversity, ensuring a permanent water table, climaponds handling stormwater directly from the downspouts can be established. The trench in the inlet can be designed, so the inlet flow is smooth, even throughout cloudbursts.

Ditches
A ditch is a narrow channel dug in the ground, typically used for drainage alongside a road or the edge of a field.

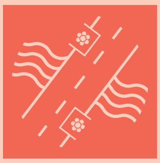
Infiltration from surface
Infiltration from surface occurs when disconnecting the downspouts and discharging the rainwater on the permeable surface.

Linear drainage systems
Using linear drainage systems makes it possible to transport stormwater visibly just underneath the road. The linear drainage systems can carry heavy traffic. It can also be in the form of steel drain grates in a driveway or concrete drain grates alongside a motorway.

Rain gardens
A rain garden is a depression in the terrain designed to receive, store and filter runoff from roofs or surfaces and is also designed as a specially planted area with selected plants that can cope with dry and with wet conditions.



Swales
A swale is a rain garden placed in the side of a road, with a soakaway underneath. Typically, the swale also serves as a traffic harassment.

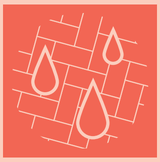


Underdrains
An overlooked NbS is underdrains. Combined with all other NbS elements, underdrains contribute to distribute the stormwater into - or out from - the NbS, optimising infiltration rate from the NbS or securing a far bigger infiltration area.

Climate roads
Permeable asphalt is getting more common. The stormwater infiltrates through the surface and the bearing layers underneath, ensuring the water transport through all roadbox.

Green roof and walls
Green roofs/walls are roofs covered with a multi- layer system consisting of: growth medium, drainage layer and water-proof membrane that delay runoff. The degree of delay and volume reduction increases with the thickness of the growth medium. Green roofs/walls insulate structures from heat and can provide a habitat for certain insects and birds. Retained water evaporates.

Irish crossings
Using Irish crossings, the stormwater is able to cross a road, whenever this is needed. The trench is shaped as a pre-immersion in the asphalt itself.



Permeable pavement
Permeable pavement provides a horizontal surface suitable for walking or driving with (heavy) traffic load but also allows rainwater to infiltrate. The infiltration capacity of the permeable pavement depends on the design and on the hydraulic capacity of the bearing layers underneath.

Soakaway or infiltration trench
A soakaway (dry well, infiltration well) is a pit in the ground, stabilised with a porous material. Wrapped in geotextile and covered with topsoil and vegetation. An infiltration trench is a soakaway shaped geometrically like a trench, for example, 60 cm wide, 1 m deep and several metres long.

Trenches
Trenches are used for transporting water above ground in places where open trenches do not inconvenience road users. Trenches can be a recreational element in an urban landscape.

Mix of NbS
All the above mentioned NbS can be combined in many different ways. Permeable pavements, linear drainage systems, raingardens, underdrains are all pieces of a larger puzzle, all contributing to the water infrastructure of climate adaptation.

Climate adaptation and social sustainability

A radical renewal by BOGL has transformed community park Remisepark from an anti-social area to a destination. The project was part of a larger local transformation to improve safety for the surrounding social housing complex and protect the area against flooding.

Remisepark solves social and climactic challenges through landscape architecture. The transformation addressed local residents' sense of security, while adapting the space to withstand the increasing pressures of flooding and improve local biodiversity.

The project ties together different park areas and activities, while enhancing its existing qualities. A snaking path connects different sections while respecting the footprint of existing trees. The path's outer edges provide a guide for the visually impaired, and improved lighting has made the park feel safer. A newly planted Alder forest and wadi collect and lead rainwater, and raised footbridges make the area accessible even when flooded.

Remisepark has successfully combined a huge number of functions without removing much-loved existing spaces. The park has created a new narrative and sense of local pride, as a space for community-building, physical activity, and nature experiences in an otherwise densely built-up area.

CONTRIBUTORS

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LOCATION

Copenhagen, Denmark

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