NATURE BASED SOLUTIONS

Using rainwater as a resource to create resilient and liveable cities

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Nature Based Solutions
Using rainwater as a resource to create resilient and liveable cities
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Front page photo
Climate adaptation at Taasinge Plads in Copenhagen
Photo: Kontraframe

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EXECUTIVE SUMMARY

Population growth, increasingly polluted drinking water, floodings and more frequent and longer periods of droughts all encourage an optimised use of rainwater in cities. Climate adaptation seeks to lower the risks posed by the consequences of climate change, including flooding that arises from extreme rain events. However, when approached holistically it can also be used to create synergies between a number of urban challenges by addressing several areas of urban development at the same time e.g. turning urban areas green, whilst at the same time reducing heat islands. In this respect, Nature Based Solutions (NBS) can play a key role in urban water management and contribute to building cities that are attractive for people to live, work and play in.

This white paper features lessons learned from a range of Danish stakeholders within rainwater management and NBS. It is supported by state-of-the art case examples demonstrating how rainwater can be used as a resource to create more resilient and liveable cities.

Multifunctional solutions create more resilient and liveable cities
A large number of synergies and cost-efficiencies can be achieved when rainwater management is integrated into overall urban planning. Cities around the world are increasingly concerned with becoming more resilient to the effects of climate change, including reducing the risk of flooding and rising temperatures. At the same time, many cities are focusing on securing an ample supply of clean drinking water that can sustain a growing population. Denmark is working towards creating multifunctional solutions which – in addition to managing rainwater and reducing the risk of flooding – also create added value for cities as they contribute to maintaining a sustainable water balance and result in new, attractive recreational areas.

Find inspiration for your own NBS projects
The content of this white paper is intended as a tool for international stakeholders who wish to gain insight into the many potentials of using Nature Based Solutions, gain an overview of how solutions have been implemented in Denmark and around the world, or who are looking for Danish partners to collaborate with on projects in their own country.

We hope you will be inspired.

SHAPING TOMORROW'S CITIES THROUGH NATURE BASED SOLUTIONS

"Denmark's experience shows that climate adaptation and rainwater management can be turned into an opportunity to create not only more resilient but also more liveable cities"

Lea Wermelin, Minister for Environment, Denmark

As the climate changes and the number and frequency of rainfall events increases, so does the need for intelligent rainwater management solutions. Like many other countries, Denmark has experienced the consequences of a changing climate first-hand. Over the past decade, we have witnessed extreme rain events that have caused flooding and damages to homes as well as infrastructure.

According to the Fifth Assessment Report from the IPCC, we can expect even more frequent and more extreme weather events in the years to come. Finding new and innovative solutions to managing rainwater in our cities should therefore be a focal point for cities and water utilities around the world.

Increasing pressure on sewerage systems

Increasing precipitation caused by climate change is putting greater pressure on our sewerage systems. However, rather than simply replacing existing pipes with larger ones, benefits can be achieved by focusing on more intelligent rainwater management which detains the rainwater in existing structures or distributes it to areas where it creates the least damage. Efforts to create more climate resilient cities are well underway in Denmark where we have had with a national action plan for a National Action Plan for a Climate-Proof Denmark since 2012. Today, all municipalities must have a local climate adaptation plan, which addresses the specific climate change-related risks in their area.

Nature Based Solutions

More and more Danish cities and water utilities are looking into managing rainwater as close to the source as possible and diverting it away from the sewerage systems and wastewater treatment plants, thereby bringing down the risk of combined sewer overflows. Solutions that manage increasing volumes of rainwater span from hydraulic models for the planning phase to solutions for local detention of rainwater such as subsurface infiltration beds, green roofs and permeable paving, to drainage solutions such as separate sewers for rainwater and sewage water as well as local rainwater treatment via roadside infiltration beds etc.

Multipurpose solutions enrich the city

By combining climate adaptation measures with exciting urban development, Nature Based Solutions can contribute to making cities not only more resilient to climate change but also more attractive places to live.

The best examples of Nature Based Solutions succeed in solving more than one problem at the same time. Holistic solutions, however, require close collaboration between authorities, water utilities, organizations, private companies and individuals. Denmark has a long tradition of such collaboration. This has brought us far. We are proud of our results and solutions. And we are eager to share our experiences and lessons learned with other countries.

Join us in Copenhagen for the IWA World Water Congress & Exhibition

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.

Until then, I hope you will be inspired by the many solutions in this white paper.

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1. FROM CLIMATE ADAPTATION TO GREEN URBAN DEVELOPMENT

Using rainwater as a resource

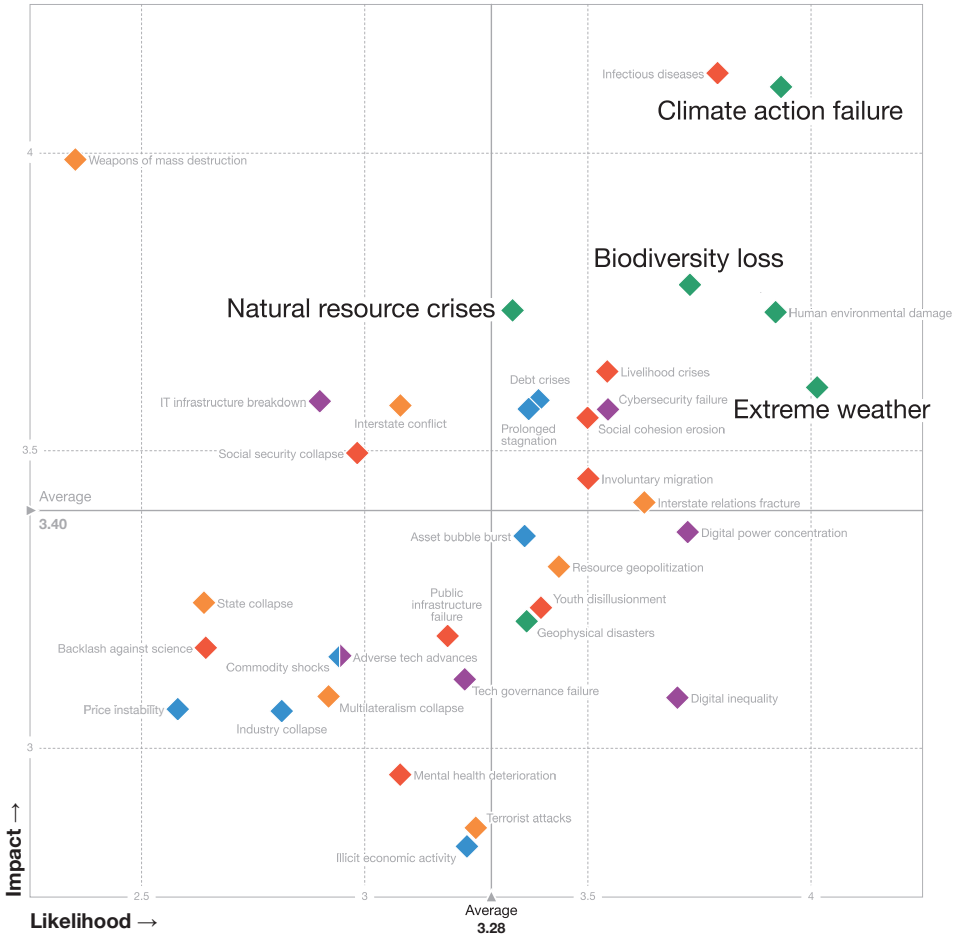
"Copenhagen is preparing for the changing climate. We want to make sure that investments in flood prevention also benefit the Copenhageners and their everyday life, therefore citizen involvement is key. In the Cloudburst Plan, we aim to create spaces that increase urban nature, biodiversity and create places for citizens to meet, when not being used for water management"

Ninna Hedeager, Mayor of Technical and Environmental Affairs at the City of Copenhagen

Many factors such as population growth, increasingly polluted drinking water, flooding and more frequent periods of drought necessitate optimised rainwater usage. According to World Economic Forum, the most likely and most impactful global risks as of 2021 is (amongst others) extreme weather, biodiversity loss and natural resource crises (see illustration below). As urban environments are expanding and more people are living in cities, there is a need to green our cities and make them more sustainable, as well as ensure a sustainable water balance in the city. Appropriate rainwater management e.g., through Nature Based Solutions, can make cities healthy, sustainable places to live and thrive in by reducing heat islands, increasing resiliency to climate change and making water more sustainable as a whole, by reusing rainwater for different purposes.

In this white paper, you will be presented with the various possibilities of using rainwater as a resource, as opposed to considering it as something that should be directed to the sewers. The aim of using rainwater as a resource is partly to reduce the risk of flooding by optimising rainwater management and partly to contribute to creating more green and liveable cities. In this sense, adapting to a changing climate and developing attractive urban spaces for people to enjoy become two sides of the same coin. As illustrated by the case examples, there are many synergies and cost-efficiencies to be achieved if rainwater management is integrated into the overall urban planning. The key is to have the right tools and models to ensure a correct prioritisation of efforts and suitably designed rainwater management solutions as well as involving relevant stakeholders at the right time throughout the process.

Several benefits can be achieved by using rainwater to help cities maintain a sustainable water balance via various treatment technologies. These ensure the proper treatment of rainwater, where it infiltrates into the groundwater aquifers or is discharged into local water environments such as lakes or streams. Finally, in areas suffering from water scarcity, local rainwater harvesting and recycling can be a valuable source of non-potable water, which can be used for watering plants, flushing toilets or washing clothes instead of using precious drinking water.



Source: World Economic Forum Global Risks Perception Survey 2021

Photo: COAST Studio, Rasmus Hjortshøj

Creating a forest and low ravine for rainwater storage, Copenhagen, Denmark

Remiseparken was a hidden, slightly neglected, green gem in Copenhagen, located in the middle of a social housing complex known as 'Urbanplanen'. The renewal of Remiseparken therefore plays an important role in making Urbanplanen a safer and more attractive area as well as functioning as a green, dual-purpose, climate adapted area.

A small forest of 20 different species of alder trees (Elleskoven) in Remiseparken delay water during periods of heavy rainfall. The forest is a new, natural space in the park, and it is designed with a particular focus on climate and biodiversity. Elevated footbridges and plateaus invite park visitors to take a walk or sit and linger. These constructions also make it possible to explore the forest even after it has been flooded by stormwater following a heavy rainfall event. Rainwater is also collected in a wadi-like trench that runs along the edge of the park. Combined, these solutions form a large delay basin with a total capacity of 2,000 m^3. The different plant species in the forest and the wadi contribute to a high degree of biodiversity and resilience, and also attract a rich selection of animals, insects and birds.

Courtesy: BOGL , Rambøll

Copenhagen Cloudburst Management Plan, Denmark

Copenhagen has experienced a number of extreme rainfall events since 2010 and the frequency of these types of events are predicted to increase in the future. As extreme rainfall events present enormous challenges (which vary from area to area), they cannot be solved by a single initiative such as upgrading the sewerage system. For this reason, the City of Copenhagen decided to coordinate and consolidate actions into a Cloudburst Management Plan that was launched in 2012, and which has been continuously updated since.

The plan outlines the methods, priorities and measures recommended to address climate adaptation, including extreme rainfall events. It designates seven water catchment areas and has resulted in a catalogue of approximately 300 surface projects that will be implemented over the next 20 years. When prioritising which projects to initiate, the city considers factors such as the hydraulic aspects in establishing the sequence of projects, where the risk of flooding is greatest, where it is easy to start, where other construction work is already planned and where synergies with urban development are possible.

Courtesy: City of Copenhagen

2. MANAGING RAINWATER WITH NATURE BASED SOLUTIONS

NBS a tool for climate change adaptation and increasing urban biodiversity

Nature Based Solutions (NBS) are measures that encapsulate the notion of water as a resource. NBS support a triple bottom line of planet, profit and people, where the aim is to heighten urban resiliency. At times, NBS solutions 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. Examples of typical NBS elements are defined on page 9.

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 Nature Based Solutions as an extension to the traditional sewerage system, the aim of NBS is to smooth 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

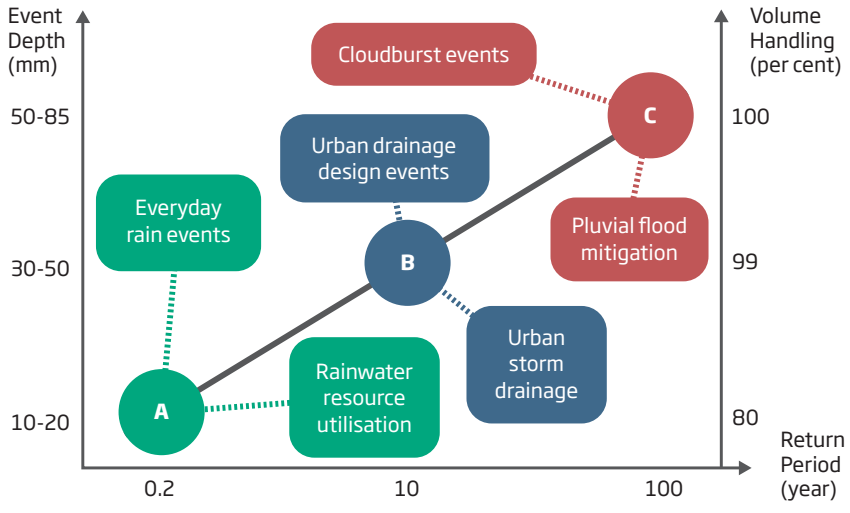
In Denmark, there is no standard definition of how to design NBS. In practice, the recommendation is that every time you design an NBS, you need to consider everyday rain, design storms and cloudbursts (as illustrated in the 3-point approach method below). Often professionals and stakeholders tend to 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. Learn more about the testing facilities at www.climateadaptationlab.dk.

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.

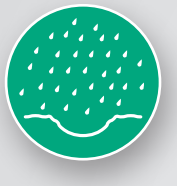


The 3-point approach
Pinpointing three main domains where decisions related to stormwater management take place.

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).

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 conrete 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.

3. CROSS-DISCIPLINARY COLLABORATION IN CLIMATE ADAPTATION

Creating synergies and saving costs through collaboration between different stakeholders

Water crosses both administrative and geographical borders. Danish experience shows that collaboration across disciplines and institutions can create valuable synergies; resulting in greener and more liveable cities with a higher degree of recreational value for the local community that also increase biodiversity and lift environmental standards. The collaborative approach is, however, challenged by the fact that the different parts of the water cycle, i.e. sea, sewage, rainwater, rivers, lakes and groundwater, are often regulated by different legislative bodies.

Legislation and financing mechanisms in Denmark

The responsibility for climate adaptation is often divided between municipalities, water utility companies and private property owners. This is also the case in Denmark. Danish municipalities are required to include climate adaptation plans in their local development plans. In order to assist the municipalities, the Danish Nature Agency has developed a set of guidelines and tools for climate adaptation plans, providing inspiration on how municipalities can manage climate adaptation as part of their overall planning process to create green-blue liveable cities of the future.

In correlation with the Danish Water Sector Act, expansions of the sewerage system are managed by water utility companies and financed through water tariffs. Due to a specific co-financing regulation, water utilities can help municipalities and private owners finance climate adaptation projects. The financing can be given to projects that are based on above-surface solutions, such as roads, water courses and recreational areas. As Danish water utilities have a monopoly on managing water and sewage, their activities and investments are regulated by the Water Utility Secretary under the auspices of the Danish Competition and Consumer Authority, which secures efficiency and high standards on water quality, security of supply and general performance.

Early stakeholder involvement is crucial

Using a cross-disciplinary, cross-institution and watershed-based multiple stakeholder approach can increase the sense of ownership by parties involved, of solutions such as NBS. Furthermore, by using this holistic approach, solutions often have a higher degree of synergy with other activities taking place in the municipalities. The results are often more liveable cities with a higher degree of recreational value for the local community and higher environmental standards.

Experience from Danish NBS projects shows that when city planning, construction, environmental issues, financing mechanisms and stakeholder relations are all addressed early on in the project's development phase, NBS projects are more likely to become successful. It is thus crucial to identify all relevant stakeholders and invite them to start a dialogue as early on in the process as possible.

Sustainability and digitalisation as a platform for collaboration

To create the necessary momentum and ownership of climate adaptation projects, urban planners, environmental managers and engineers from the municipal departments often join forces with engineers and planners from water utilities at an early stage. To ensure buy-in from the local community, local citizens, property owners, local businesses and environmental NGOs are also involved in the process. A strong use of digital tools and platforms make the project more accessible for all stakeholders, including the ability to follow and comment on the project as it takes form. Using the UN Sustainable Development Goals as key performance project indicators ensure both the right project design and increased local community engagement. This could be a local partnership using climate adaption projects to flood drained low-lying farmland and wetlands, reducing greenhouse gas emissions and urban flooding and at the same time creating more biodiversity, nature and areas for recreation, contributing to SDG 6, 11, 13, 15 and 17.

Cross-disciplinary collaboration in Denmark

DNNK, Danish Network for Climate Adaptation (established in 2020) is an innovation network consisting of more than 150 knowledge institutions, government agencies, municipalities, water utilities and private companies (tetrahelix structure). The purpose of DNNK is to develop, document and present climate adaptation technologies and associated planning tools for the transformation of existing urban areas in Denmark. All information and experience with NBS in Denmark have been compiled on the website:

https://en.klimatilpasning.dk

Photo credit: LYTT Architecture

Engaging and mobilising the local community in creating a Climate City in Middelfart, Denmark

Covering an area of 450,000 m^2, "The Climate City" project in Middelfart demonstrates how to integrate climate adaptation with urban development. Through a dialogue based co-creational process, the municipality and wastewater utility have worked closely together with landscape architects, engineers, local citizens and other stakeholders in developing the project. From the programming phase, through the architectural competition process and subsequent project development and detailed project design, citizens have actively contributed with local knowledge, comments and ideas. The Climate City project, which focuses on climate adaptation through urban design of public areas, also functions as a driving force, which inspires local home owners to manage rainwater within their own gardens. Therefore, The Climate City is to a great degree about mobilising the local citizens to become an integrated part of the project. The Climate City is a partnership project between Middelfart Municipality, Middelfart Wastewater Utility and the philanthropic organisation, Realdania.

Courtesy: Middelfart Municipality, Middelfart Wastewater Utility, Realdania, Bascon, WSP, LYTT Architecture and ADEPT

Separating rainwater from wastewater on the surface, Aarhus, Denmark

The Municipality of Aarhus has a vision of making the city an even more attractive place to live through its climate adaptation projects, and the local water utility, Aarhus Vand, works closely together with the municipality to fulfill this vision.

Together, they make rainwater a visible element in the form of rainwater lakes, rainwater beds and rainwater drains. They establish hollows and dams, create entirely new urban spaces and find new ways to lay out green areas. In this way, rainwater is handled in a combination of pipes and surface solutions, using various Nature Based Solution (NBS) elements.

The citizens can choose either to handle rainwater on their own plots, or to lead the rainwater to a nearby public area via the surface, where Aarhus Vand handles it. Getting citizens on board on a project such as this is a crucial task. Thanks to a successful citizen involvement process with a combination of workshops, extensive FAQ's and even individual advisory sessions on private plots, the house owners embrace the new recreational solutions.

Courtesy: Aarhus Vand, EnviDan, Aarhus Municipality

4. NATURE BASED SOLUTIONS IN SIMULATION MODELS

Assessing the urban water cycle and the impact of NBS

As many cities around the world are experiencing more frequent and heavier rainfalls, simulation modelling tools to help predict and understand the urban water cycle are proving ever more pertinent. Modelling different scenarios of terrain flooding from sewer overflow or the impact of implementing NBS to the entire urban water cycle can aid decision makers in prioritising the projects needed to handle future incidents of rain. In Denmark, the very first simulation models of the sewerage system were produced in 1985. Since then, the need to be able to simulate the whole water cycle in detail has only become more pressing, what with the heavier rainfalls the country have experienced over the last decade and new water-sensitive urban designs to handle them. Climate change scenarios have become an integral part of urban water cycle management.

Future climate change scenarios for Danish cities predict an increased frequency of extreme rainfall events that cause floods and massive damage to buildings and infrastructure. Similarly, rising sea levels, increased river flows and higher groundwater levels are expected. To meet these challenges, massive investments in flood protection and climate change adaption measures are required. By using urban water simulation models, decision makers are able to decide upon and prioritise their efforts, as the models help quantify the effects of investments. Thereby it is possible to minimise the risk of poor investment strategies.

Hydraulic model of NBS elements as part of sewerage systems

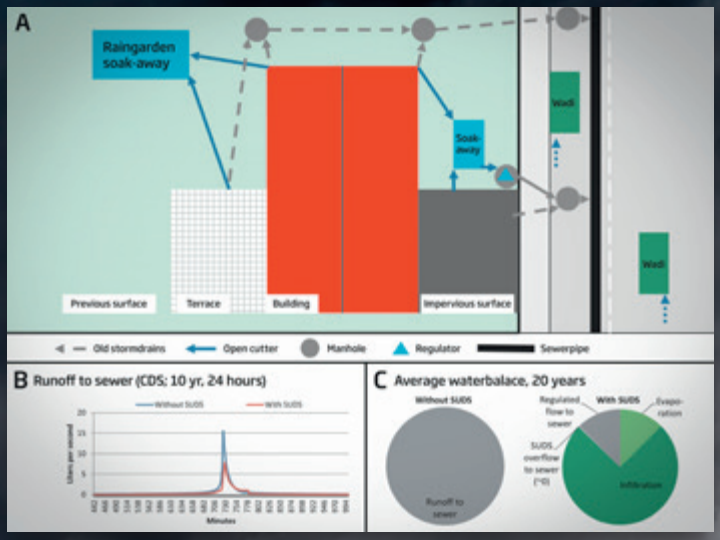
When using simulation models, it is possible to quantify the hydraulic effect of water-sensitive urban designs versus expansions in grey infrastructure such as larger pipes or traditional basins in a sewerage system. The models simulate the impact of rain events; calculating water depth and flow in the sewers and manholes, and rivers related to different rain events – and also calculate the extent of flooding at the terrain. The models can simulate where overflows and flooding will occur and which effects the different solutions will have on the water level, the overflows and on the risk of flooding, as well as the extent of the damage to buildings and infrastructures. In addition, the effect of NBS on water quality issues can be simulated. The simulation model, MIKE+, makes it possible to create an overall hydraulic assessment of implementing different green solutions in a catchment area, such as rain gardens, swales, infiltration trenches, permeable pavements, barrels and green roofs as an extension of the existing sewerage system as well as modelling bioretention cells and other green solutions hydraulically. The MIKE+ is an integrated modelling platform for modelling collection systems, rivers and flooding.

Urban hydrological models and NBS

Another type of simulation model 'MODFLOW-URBAN' focuses on the entire urban water cycle and the consequences of applying NBS instead of sewer-based pipe systems. The model can simulate typical NBS features such as green roofs, rainwater tanks, swales, infiltration devices, and overflow from one NBS feature to another. Other significant processes in the urban water cycle are simulated, i.e. runoff from semi impervious and impervious surfaces, infiltration through the unsaturated zone to the groundwater, groundwater flow within hydrogeological layers and groundwater-related interactions with wells, rivers, channels as wells as suburban infrastructures such as leaky sewer pipes, drainage pipes and infiltration trenches.

A key model characterisation is the detailed simulation of NBS on allotment scale and the upscaling to neighbourhood and city level scale. Thus, the effect on the groundwater table from several infiltration devices can be simulated and used to analyse the risks of a shallow water table causing damage to building foundations, basements, road infrastructure etc. Similarly, the model can be used to design and simulate drainage features – possibly in combination with NBS – to prevent a rising urban groundwater table. Catchment runoff (i.e. stormwater runoff, drainage and overflow from NBS structures) can be given as input to sewer pipe models to simulate the hydraulic consequences from NBS on sewer overflows and flooding events. The model can therefore be used in the planning of sustainable Nature Based Solutions and drainage strategies for neighbourhoods, and can reduce the risk of poor investment strategies.

Figure 1:



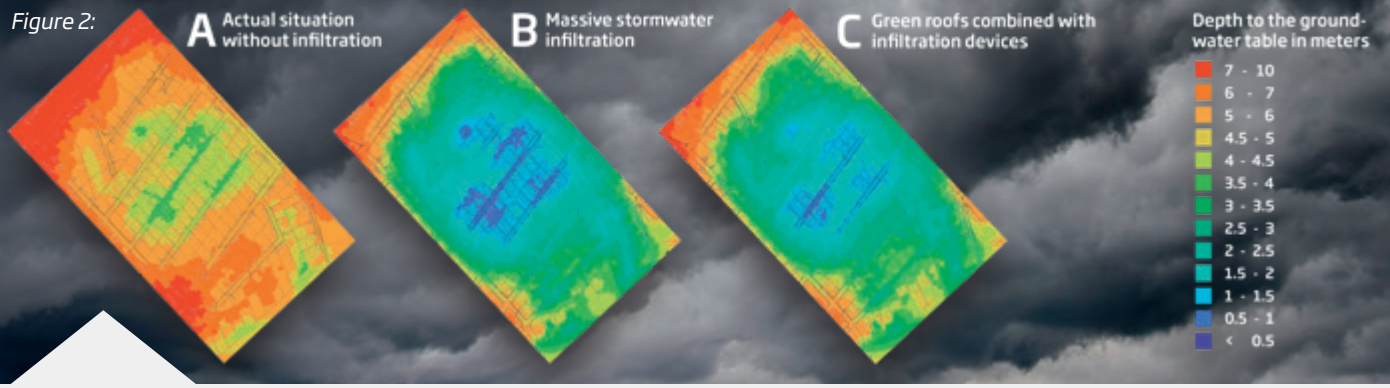
Simulation of a NBS-strategy on allotment scale:

A *Drawing of NBS elements and the direction of stormwater;*

B *Simulated accumulated runoff to the sewer system in a 10 Yr design storm;*

C *simulated average water balance.*

Figure 2:



Simulation of sustainable stormwater infiltration strategies in Odense, Denmark

The developed urban hydrology model 'MODFLOW-LID' was demonstrated for case-areas in the city of Odense. Different NBS-strategies were simulated on detailed scale (Figure 1) and upscaled by the model to neighbourhood scale (Figure 2). NBS-strategies included the use of rainwater tanks, green roofs, raingardens and soakaways on private parcels as well as swale-trench systems with water brakes and overflow to the existing sewer system underneath roads. Special attention was given to the simulation of rainwater harvesting (rain tanks) and green roofs in combination with infiltration devices to manage sustainable infiltration strategies in terms of both maximising the infiltration, minimising the risk of a shallow groundwater table underneath buildings and delaying stormwater runoff to the existing sewer system. As the illustration in figure 2 shows, the model was used to simulate different stormwater infiltration strategies and the associated depth to the groundwater table in a residential area: (a): actual situation (baseline scenario) without stormwater infiltration; (b): massive stormwater infiltration leading to a critical shallow groundwater table in low-laying parcels; (c): the use of green roofs to reduce stormwater infiltration volume leading to less critical depth to the groundwater table.

Courtesy: The Foundation for Development of Technology in the Danish Water Sector - VTU, NIRAS, VCS Denmark, Municipality of Odense, Aarhus University, GEUS

Evaluation of flood management in Malmö, Sweden

The area of Augustenborg in Malmö, was retrofitted with a green open stormwater system in the late 1990s. When a major rainstorm hit the city of Malmö in August 2014, Augustenborg was less affected by flood damage than nearby areas. Since the retrofitting of the stormwater system, it was unknown if the solution was efficient for extreme rainfall events with a 100-year or higher return period.

The nature based stormwater solution in Augustenborg, consists of open canals, swales, ponds and green roofs as well as adapted levelling of green areas to ensure controlled flooding. A model of the system was set up in the simulation software MIKE FLOOD. This included the rain on grid and infiltration, to enable correct quantification of stormwater infiltration in green areas. A scenario of the current stormwater system and one for the old pipe-based system was created. This methodology allowed for evaluation on comparison of the two. Results showed that the retrofitted green stormwater system would result in an approximately 80 percent lower discharge and hence substantially decrease the risk of flooding.

Courtesy: Division of Water and Wastewater Engineering Lund University, DHI, VA Syd (Water utility in the city of Malmo)

5. BREAKING THROUGH THE SURFACE

Managing rainwater in densely populated areas with impermeable paving

Due to the increasing amounts of large, impermeable surfaces in cities, the rainwater runoff from a city differs from the natural runoff pattern that occurs prior to urbanisation (as explained in chapter 2). When impermeable surfaces are the main types of surface present in an area, the runoff from several catchments will arrive simultaneously in certain sections of the sewers, where the capacity of the pipes is lower than the accumulated flow. The lack of capacity creates bottlenecks in the sewers, increasing the risk of flooding. When establishing NBS, peak runoff is delayed and reduced, which, in a majority of cases, also minimises the risk of flooding.

Replacing impermeable pavements but preserving the carrying capacity

When establishing NBS in a densely populated city, it is important that the functionality of the base surface - including the carrying capacity - is preserved. This is possible when paving roads or streets with permeable asphalt, or when using permeable tiles in the pavement or at the parking lot. Permeable paving allows transportation, storage and delay but in general, there is no evaporation.

Considering infiltration from areas with permeable paving, experience from Denmark shows that it is possible to construct permeable paving both with - and without - infiltration. For instance, if the municipality is worried about the water quality of runoff from a large parking lot, it is possible to construct permeable paving with a membrane underneath and lead the runoff through pipes into a sampling well. Sampling can be carried out at a specified frequency that the municipality determines. This makes it possible to document the quality of the runoff from the parking lot and based on this, assess whether it will be possible to allow runoff to be infiltrated in the long run.

Permeable asphalt: the principle of the climate adapted road

In general, the principle of the permeable road is to allow water in the road construction, as both the wear layer and the base layer are permeable. When using permeable asphalt to store and delay rainwater, several issues need to be taken into account. Firstly, it requires a mental leap to allow water into the construction of the road – a major shift from traditional designs that ensure no water is entering the road construction. When allowing rainwater in the road construction, the lifetime of the asphalt has to be considered as well as the lifetime of the permeability layer. What is the risk of the asphalt clogging, which will prevent infiltration of the rainwater into the construction of the road? How can this risk be minimised? In addition, traditional requirements need to be considered, such as noise reduction, rolling resistance (see figure 3) and not least, safety.

Although this is still relatively new territory, Denmark has accumulated enough experience to present the first answers to these questions, thanks to a new method of maintenance and operations, which is a focal point when using permeable asphalt to ensure a long lifetime of the permeability.

Figure 3: Functional requirements of the road. Permeability is one of the requirements, which is ensured by periodical and thorough maintenance and operations.

Retention and infiltration of rainwater in a schoolyard in Horsens, Denmark

Increasing amounts of rainfall heighten urban planning challenges. This also applies to municipal institutions, such as schools. The Danish primary school, Østerhåbskolen, which is located in the southern part of Jutland experienced flooding in the schoolyard during periods of heavy rainfall. The challenge was to find a solution for managing rainwater in the schoolyard, which consists of an area of 187 m^2 and has a water capacity of 179 m^3. By using a new generation of AquaCell rainwater cassettes for rainwater retention and an infiltration tank, it was possible to allow for the right amount of water storage to be accomodated. The AquaCell cassettes are made of 100 per cent recycled PP and can hold up to 96 per cent of their volume. Due to the stackable design, the contractor could easily store the 648 cassettes in the schoolyard while the installation took place. With the retention and infiltration solution in place, the risk of flooding the schoolyard has been reduced considerably.

Courtesy: Wavin

Obtaining climate adaption in grocery store car park, Hedensted, Denmark

The City of Hedensted has experienced of the costly aftermath of heavy rainfalls that are occurring with increasing frequency in many countries. As such, implementing climate adaptation measures has become a priority in the area. Therefore, when the supermarket chain Lidl wanted to open a new store in the area, they included rainwater management in their planning from the outset.

The store had a car park installed that deals not only with the rainwater that falls on the parking area, but also with the rainwater from the roof of the store. The roof runoff is led under the car park's asphalt, enabling the runoff to be handled together with the rainwater that falls on the car park. The parking area consists of a permeable asphalt coating and a unique base layer, with the same drainage capability of a traditional fascine. This ensures that the water does not flood or form puddles in the car park and that the water drains slowly into the ground, rather than straining the sewage system.

Courtesy: NCC, Lidl

6. INCREASING URBAN BIODIVERSITY

Creating green corridors and resilient cities by integrating nature into urban life

Globally, biodiversity is under pressure and the majority of the dying species are threatened as a result of human activities. Vital ecosystems are weakened and food chains are destroyed. In Denmark, consecutive governments have worked to reverse the decline in the diversity of the country's nature by creating contiguous and resilient nature areas with improved living conditions for native animals and plants. Another benefit of such areas is the creation of enhanced outdoor experiences for the local community.

Bringing nature back into the cities

The occurrence of NBS solutions such as green roofs, rain gardens and swales can contribute to increasing local biodiversity. NBS and the water cycle are becoming the focal point when creating green corridors and resilient cities by integrating nature into urban life.

It is possible to choose a strategy for the chosen plants in NBS elements to support certain insects (e.g. bees or butterflies) and thereby birdlife, amphibians and/or native plants. Denmark has experience with strategies that support native plants which serve as habitats for certain species – for example salt marshes or meadows. The concept is called 'Urban Green' where the plants are selected to ensure that the composition of the plants support each other, forming a symbiosis between the different plants. The concept is bringing nature back into the cities and creating wild, green and blooming lushness everywhere via rain gardens, swales and green roofs.

In addition to improving green corridors, NBS also offer a number of other benefits for urban life. For example, the urban heat island effect, i.e. higher temperatures in cities compared to the surrounding countryside, is reduced locally when the number of green areas is increased. There is also a growing overall trend among architects and city planners to find inspiration in nature and to consider both nature and wildlife when planning and designing new urban areas.

Using rainwater to combat urban heat-island effect with Green Bus Stops, Poland

Many cities today suffer from Urban Heat Island effect (UHI) and excess of rainwater runoff in the streets, creating challenges for liveability and causing costly damages to infrastructures. Four cities in Poland have chosen to use the Green Bus Stop as a Nature Based Solution to reuse rainwater as a resource and contribute to the reduction of UHI effect.

The green roof of the Green Bus Stop can retain up to 90 per cent of the rainwater falling on its surface. The excess of rainwater falls into an underground rainwater container, where the rainwater can be stored and redistributed to the surrounding areas. Vegetated ground boxes around the bus stop can also retain rainwater and create stepping stone habitats for the local fauna (e.g. insects, birds). During intense rain events, the excess storm water is drained with patented internal vents, into the vegetated boxes containing optimised drainage layers. Any excess rainwater from the boxes is led to sewers or nearby green areas. Besides adding ecological connectivity and biodiversity to urban areas, the Green Bus Stop emits less heat than the traditional counterpart does, at times as much as 10°C less.

Courtesy: Amphi Consult & FPP Enviro

The Lakeside Garden in Singapore
Once a mangrove swamp, the Jurong region in the South-Western Singapore is being developed into a new business and leisure destination called the Jurong Lake District. The Lakeside Garden is the first phase of the Jurong Lake Gardens, which is the recreational area of the new district.

One of the most visible features of the garden is the 'Rasau Walk', which is a winding, barrier-free, waterfront boardwalk along the Jurong Lake shoreline. Other features include grasslands for bird hides, islands for herons and a stream forest, which is a suitable habitat for dragonflies. All fallen trees have been repurposed into site furnishing and landscape features such as bird platforms, habitat logs, pathway curbs or nature trail features - all in order to support and improve biodiversity.

There is a nature-inspired play area, which is the largest of its kind in the country. It offers a variety of experiences for children, such as the opportunity to crawl through a 'squirrel's nest' and glide through a tree canopy. Jurong Lake Gardens is a park where people, animals and plants can co-exist and mutually benefit.

Courtesy: Ramboll

It's raining frogs: stormwater solution improves biodiversity in Alleroed, Denmark
Heavy rain events have caused multiple sewer overflows in Lynge, a district of Alleroed Municipality that is located north of Copenhagen. The area was previously a marsh area, which could store large volumes of stormwater, but due to drainage, Lynge had lost parts of its natural character over time. With a combination of landscape-based stormwater solutions and nature improving initiatives, Alleroed Municipality decided to improve stormwater management, increase biodiversity in Lynge and improve conditions for the recipient, Lynge Stream. The developed stormwater solution holds back stormwater in dry and wet basins, and slowly discharges it into Lynge Stream. The result is a more stable waterflow in the stream, a reduction of the risk of combined sewer overflow to the stream as well as an increase in wet and semi-wet habitats. Exposure of mineral soil in combination with the addition of stormwater and planting of selected species is expected to increase the diversity of plant species found in the area, and in turn, increase the number of food sources for insects. Furthermore, a new pond was established to attract amphibians. The pond only receives stormwater that has passed through a dual porosity filter implemented centrally in the area.

Courtesy: University of Copenhagen, COWI, HedeDanmark, LiAn Landscape Design, Alleroed Municipality, City of Copenhagen, Albertslund Municipality and Aarhus Municipality

7. NATURE BASED SOLUTIONS AND TREATMENT OF RUNOFF

Improving the water cycle by ensuring an appropriate quality of rainwater runoff

Local management of storm water runoff in Nature Based Solutions includes the runoff to be collected, delayed and/or stored and hereafter used as a recreational asset in channels or ponds in the city or discharged slowly to a receiving water body, such as a groundwater aquifer, the ocean, streams or wetlands. However, runoff can contain a variety of pollutants such as oil components, heavy metals, endocrine disrupters, pesticides, road salt and nutrients. Therefore, runoff must often undergo treatment before being discharged to the receiving water body.

In accordance with the European Water Framework Directive and the Danish Environmental Protection Law, Danish municipalities must determine whether treatment of the runoff is required for each case that utilises NBS. This requirement depends on the pollution level of the runoff as well as the sensitivity of the recipient. Thus, when choosing a treatment solution, it is important to ensure the water can be treated sufficiently to meet the quality requirements related to the particular recipient.

If the water is infiltrated, it must not contaminate the groundwater. If the water is discharged to a lake or a stream, it must not deteriorate the biological and ecological state of the receiving body of water. And if it is used for recreational purposes, the rule of thumb is that rainwater can be stored for a maximum of 24 hours due to concerns about pathogens. If the treated runoff is to be sprayed or pumped for play, e.g. at playgrounds, UV disinfection is often necessary.

Several solutions for treatment of runoff are available and they are often already an integrated part of the NBS. These include basic treatment mechanisms such as sedimentation, filtration, absorption, biological degradation and flocculation – often in combination. Proper documentation of the treatment efficiency of the solutions is paramount to ensure that the receiving water bodies are protected. Establishing a sound, pragmatic and useful documentation procedure is still an ongoing process in Denmark, as well as in many other countries.

Maximum permissible values:
PH: 6-9
Suspended Solids: <0.1 mg/l
Iron: < 0.5 mg/l
Total Nitrogen: 4mg tot- N/l
Ammonium: 1mg NH4-N/l
BOD5: 3mg O2/l
Oxygen: 6mg/l (50 per cent saturation)

Treatment of polluted runoff surface water with Dual Porosity Filtration (DPF) in Ørestad, Denmark
In the Copenhagen suburb of Ørestad, polluted road water runoff is separated from household wastewater and cleaned by a new technology called Dual Porosity Filtration (DPF). Due to the high concentration of fine particles, dissolved heavy metals and phosphate present in the water, a water treatment solution is needed before the water can be discharged directly into nature.

By simulating nature's own cleaning process, the DPF system cleans and contributes with 110 litres of rainwater every second, directly to the nearby Nature Park Amager, which is a Natura 2000 recipient. The DPF technology is well documented and the sedimentation and absorption processes are used to clean the water, meaning there is no need for chemicals or power. In Ørestad, the system is 51x13.5 m, but due to its upcoming establishment underneath one of the area's major roads, it will not be visible in the urban environment. The DPF is compact, scalable and can be placed anywhere.

Courtesy: WaterCare Filtration, University of Copenhagen and HOFOR - Greater Copenhagen Water Utility

Treating rainwater through curb extensions, Hørsholm, Denmark

Sewer capacity is often maxed out during periods of heavy rainfalls. Therefore, an unconventional management approach to rainwater from roads has been applied to Gyvelvej in the city of Hørsholm. A technology which is becoming more widespread in relation to treating dirty runoff water from roads is Nature Based Solutions. By using alternative methods for handling road water, a double profit is gained in the form of a decreased load on the sewer system and a facility with recreational value.

The curb extensions on Gyvelvej are constructed by using a two-section system in which the first section collects fallen leaves and sand particles. The second section of the curb extension infiltrates the rainwater through a special type of soil which binds and delays organic and nonorganic nutrients. Clean water then infiltrates into the groundwater aquifers. In the case of extreme rain events, the water is bypassed to underground infiltration trenches in order to utilise the full capacity of the system and subsequently discharge the water to the sewer.

Courtesy: WSP

8. URBAN RECIRCULATION OF RAINWATER

Using rainwater harvesting to create a city in water balance

In many areas of the world, increasing water scarcity and drought is a highly critical problem, forcing cities and countries to focus on how to harvest and optimise the reuse of rainwater. In Denmark, water scarcity has not yet been a serious issue, but climate change predictions indicate that prolonged drought periods will occur more frequently in the future.

The water balanced city

A recurring objective for cities that invest in rainwater harvesting and recycling is often to ensure that the city is able to rely on the water resources available within the city limit. Many cities are faced with rising population growth due to increased urbanisation. Rainwater harvesting and recycling rainwater can assist the city in maintaining its overall water balance in spite of a growing population, thereby managing urban water in a sustainable manner. The International Water Association has developed a comprehensive framework for sustainable urban water management, resilience and liveability. Its approach, which is termed 'Water-Wise Cities', consists of 17 principles supporting four highly interconnected actions; Regenerative Water Services, Water Sensitive Urban Design, Basin Connected Cities and Water-Wise Communities.

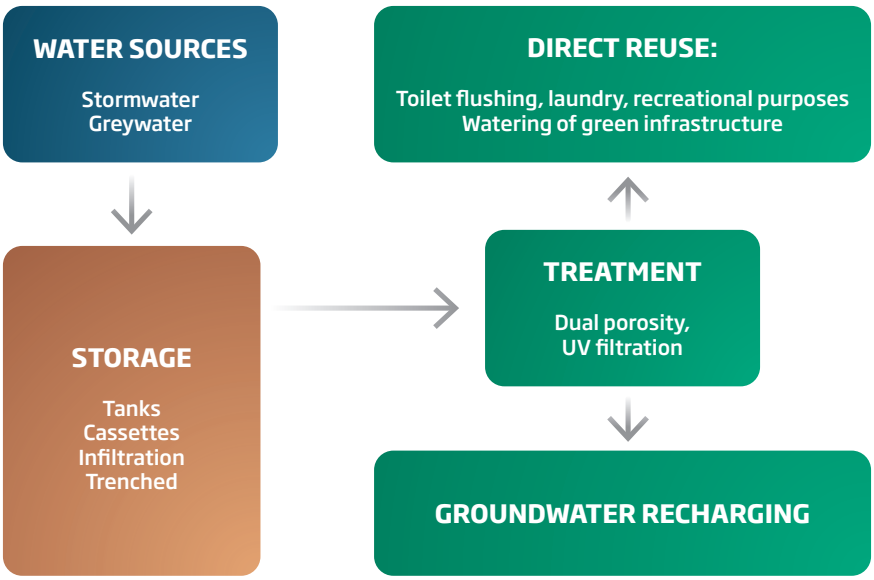
The Danish innovation consortium 'Cities in Water Balance' aims to provide urban climate adaptation options that address both the increased risk of rainwater flooding and the increased risk of drought by linking rainwater management systems either directly or indirectly to water supply systems and in this way progressing towards a closed urban water cycle. Based on the overall concept of the water balanced city, it is possible to customise concepts for areas where there is a heightened risk of water scarcity.

The focal point of the water balanced city concept is how to increase infiltration, evaporation and rainwater reuse. However, the issue of leakages in the drinking water system should also be considered in order to reduce water loss. Finally, educating citizens on how to conserve drinking water and reuse rainwater should also be part of the concept. A team is put together for each case under the concept. Each team typically consists of a consortium of knowledge institutions (in charge of development of concept, documentation and teaching), consulting engineering companies (in charge of design) and contractors (in charge of establishing the system for collecting rainwater and performing leakage detection).

Safety issues when reusing rainwater

The legislation in Denmark for reusing rainwater is very strict, forcing companies to focus on optimal design and safety standards. It must be documented that there is no contact between the rainwater system and the drinking water system. Thus, there are two compulsory technical solutions to prevent the drinking water from being polluted; a physical gap between the two systems and a safety valve that prevents the drinking water from coming into physical contact with the rainwater.

The design and safety regulations are described in detail in a manual which includes guidelines for designing all parts in the system; including fittings, filters, manholes, storage tanks, pipes and the back-security valve. For instance, the size of the storage tank is designed by calculating water consumption, the amount of runoff from the roof and considerations of the residence time to reduce the growth of bacteria in the tank.



A city in water balance relies on water resources available within the city limit. Rainwater harvesting and wastewater recycling allows for population growth.

Nye - a new sustainable and water-wise suburb in Aarhus, Denmark

The vision of Nye is to create a water-wise, urban district, where it will be effortless for citizens to live sustainably. Blue/green structures will promote biodiversity in this new suburb, which is developed to manage predicted climate change. Rainwater is harvested and treated locally for re-use in households, hereby preserving groundwater resources. Rainwater from roofs, roads and recreational areas is collected in open trenches and runs to small rainwater basins, before ending in the largest basin. This creates an attractive open, lakeside space. From the large 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 phase of the project is approaching up to 650 households, where permit is given by authorities to use treated rainwater for toilet flushing and laundry. Meter data from the first 50 households shows that non-potable water use covers around 40 per cent of the total water use, confirming the expected level. Nye demonstrates a new and sustainable way of including rainwater into household use - a holistic approach to rainwater management in an urban area.

Courtesy: Tækker Group, Silhorko-Eurowater, Cowi, Aarhus Vand, City of Aarhus

Functionality and aesthetics combined at Novo Nordisk Nature Park in Bagsvaerd, Denmark

Novo Nordisk Nature Park is the first park in Denmark with a 100 per cent water balance. The park's topography and plantation are carefully designed to handle even once in a blue moon cloudburst without directing any water into sewers. The solutions have given the healthcare company, Novo Nordisk, full refund on their sewer taxes. Equally, the solution includes the creation of lush nature of a variety of dense biotopes, which maximises environmental sustainability, recreational value and conditions for outdoor meetings. Rainwater from pavements and onsite roofs is collected in an underground water tank. It is later used for irrigation of the 15,000 m^2 green roof covering the underground parking garage or led to the different biotopes via underground reservoirs. For the green roof, the DiaCell system of nonwoven geotextile with a Fortrac geonet for erosion control was installed. Two layers of geocells, soil substrate for extensive roof gardens and finally a pre-vegetated sedum/meadow mat were also installed. Any excess water is infiltrated.

Courtesy: SLA, Henning Larsen Architects, SKAG, Byggros, HedeDanmark, URBANGREEN and WSP

9. CREATING RESILIENT AND LIVEABLE CITIES WITH NATURE BASED SOLUTIONS

Using rainwater as a resource to create green urban spaces with added benefits

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 of the situation, the incorporation of various NBS can contribute to greener and more pleasant urban spaces with added benefits such as increased real estate values, increased biodiversity, increased traffic safety and additional recreational opportunities for the local 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 NBS projects 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 on, 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. As described in chapter 3, 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.

Water as a key element to creating liveable cities
Download the publication "Water for Smart Liveable Cities" to learn more about how water can serve as a key element in creating smart and liveable cities:

www.stateofgreen.com/publications

Sports centre uses climate adaption as stepping-stone for new recreational facilities in Gladsaxe, Copenhagen

Extreme rain events have caused flooding on several occasions in the Copenhagen suburb of Gladsaxe. To prevent future flooding, a large climate adaptation project was recently completed at Gladsaxe Sports Centre. The sports centre is situated on top of a large regional water system. By diverting rainwater through a series of ponds and canals, additional capacity was created in the sewerage systems both locally and in the low-lying areas between Gladsaxe and the sea. By choosing surface solutions with dual purposes rather than traditional underground reservoirs, the project saved approximately EUR 4 million, proving it to be a very cost-efficient solution. Keeping the rainwater above surface also became a steppingstone for creating new recreational areas and playgrounds. Eight different holes were constructed to function as different recreational areas when they are not used for collecting rainwater. For sports enthusiasts, the park has been turned into a concrete corridor for skateboarders and a paddle tennis field. As the holes have a more informal setting, the park now has a much wider appeal for the overall local community, who utilise the park for activities such as jogging, playing, dog walking and taking Sunday strolls.

Courtesy: Gladsaxe Municipality, Novafos, Bisgaard Landscape, SWECO, Ohlers Design, WATER PLUS, Realdania, The Danish Foundation for Culture and Sports Facilities and the Danish Environmental Protection Agency.

The climate resilient school, Roskilde, Denmark

The vision for the climate resilient school in Roskilde is to handle all stormwater on campus. To ensure this, 1,100 m² of roof has been disconnected and runoff from the pavement infiltrates through permeable pavings. Runoff from the roof runs through trenches into a paddling pool shaped like the local bay which is also used by the school children for playing and learning. From the 'bay', the stormwater goes through an ACO trench into a soakaway. The soakaway has a membrane underneath, creating storage volume for stormwater. It is possible for the children to pump up the stormwater with old-school hand-pumps. The overflow goes into a raingarden and a ditch downstream through the raingarden. From the raingarden, the water flows into a multifunctional pump track lane with parkour-elements for street climbing. The multifunctional square is covered in permeable rubber and illustrates the meeting between coast and sea. The project demonstrates that NBS are able to handle everyday rain, design storms and cloudbursts, when the different NBS elements are connected to each other as pearls on a string.

Courtesy: Danish Technological Institute, Aalborg University, DHI, Gundsoe Entreprenoer Forretning, Thing og Brandt Landskaber, IBF, NCC Roads, ACO Nordic, Wavin, Nykilde, Amphi Consult, KLS PurePrint, Municipality of Roskilde and FORS

Photo credit: SLA

Copenhagen's first climate resilient neighbourhood
An existing neighbourhood in Copenhagen has since 2013 undergone 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, the surface solutions are combined with a conventional split rainwater sewer system, which ensures a controlled transport of the rainwater to the nearest harbour.

The transformation has been carried out in different sections:

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.

Courtesy: 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.

Landscaping resilient courtyards of the future, Copenhagen, Denmark

'The Courtyard of the Future' includes a path crossing the traffic road into the courtyard, a 'garden zone', and a 'landscape zone'. Each have their own plant theme and handle rainwater in different ways.

The entire landscape zone is shaped like a ditch and can contain up to 300 m^3 water, which is enough to handle a 100-year rain event. It has a wilder appearance and invites children to play and follow the water through gutters and ditches. The garden zone is rich with orchards, rain beds, sheds for bicycling storage and a greenhouse for residential use. Here, rainwater is collected in underground water tanks, which allows the residents to re-use the rainwater later on.

Additionally, the traffic road outside the courtyard is renovated with a permeable surface, parking spaces and specially developed fascines that allow for necessary tree root growth. Because of its many attractions and functions, the courtyard is popular among the residents and now doubles as a developed urban space and rainwater storage facility.

Courtesy: NIELS LÜTZEN Landskabsarkitekter, City of Copenhagen, Kuben Management, Envidan, Labland, Urgent Agency, Courtyard project: MøllerLøkkegård, Askøgade project: Dalsgård

Cost-efficient climate adaptation and wetland restoration, Karlstrup Marsh, Denmark

Heavy rainfalls used to lead to severe flooding in the small cities of Greve and Solroed, located south of Copenhagen. Today, the increased volume of rainfall is used positively in a restored river valley with an open pond and wetlands which provide both recreational value to the citizens and improved habitats for flora and fauna. A new pond purifies rainwater before it runs to the re-established river, allowing trout and other wild fauna better living conditions. At the same time, the water utility company now has access to 30,000 m^3 of rainwater storage during stormwater events. The Karlstrup Marsh project is a unique collaboration between KLAR Utility and the two municipalities of Greve and Solroed and has created win-win solutions for everyone involved, including local sports clubs, farmers and bird watchers. In Karlstrup Marsh, climate change adaptation became a strong driver of sustainable and cost-efficient development as the project saved the water utility company construction costs for traditional urban retention basins. The holistic approach had a strong focus on stakeholder involvement, alternative financing mechanisms and not least technical solutions involving a new stream established through the local forest.

Courtesy: NIRAS, KLAR Utility, Municipality of Greve, Municipality of Solroed

Integrating rainwater as an element in the aesthetic landscape solution, Copenhagen, Denmark

Scandiagade is an innovative climate and urban landscaping project situated in one of the most densely populated residential neighbourhoods in Copenhagen. The street was originally a worn-down area, and although a few beautiful old trees were present, the area appeared empty and without proper function. In addition, the neighbourhood faced recurring challenges of heavy rainfalls flooding people's basements once the sewerage system's capacity was reached.

Today, Scandiagade is able to handle heavy volumes of rainwater as well as function as a recreational park for the local residents. It now has a central reserve, with the old lime trees transformed into an urban space with eight basins. The basins are able to contain 1,500 m^3 rainwater led from the surrounding neighbourhood. When it rains, the basins delay the rainwater, ensuring that the sewers do not overflow. When it is dry, the basins' hilly landscape hosts a number of activities such as an adventure playground, butterfly garden, a free growing experimental garden and urban kitchen gardens, as per the residents' ideas.

Courtesy: 1:1 Landskab, Nueva,
Atkins Danmark and City of Copenhagen

Green Climate Screen in Valby, Copenhagen

A neighbourhood in one of Copenhagen's most congested areas with approximately 45,000 cars passing through on a daily basis, saw an improvement in both noise from traffic, its liveability factor and the at times, heavy rain runoff.

Instead of constructing a conventional noise barrier out of e.g., steel or concrete, the vertical green climate screen is based on mineral wool, willow tree and vertically growing plants that specifically accommodate bees and other pollen-dependent insects. The 80 m long and 3 m high vertical green climate screen receives rainwater runoff from 240 m^2 roof surface, which evaporates over time, rather than increasing local groundwater levels or straining the sewers. The screen is sized to handle a 10-year rainfall event - the same as the public sewerage system.

A yard-like space now provides the residents with a useable urban space; where thanks to reduced noise from traffic it is easier to conduct conversations and stay in the dry meadow between the apartment building and green screen. The multifunctional green screen aids better air quality, heat island mitigation and enhances urban space activation.

Courtesy: Malmos, Aarsleff, 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.

WATER VISION DENMARK
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