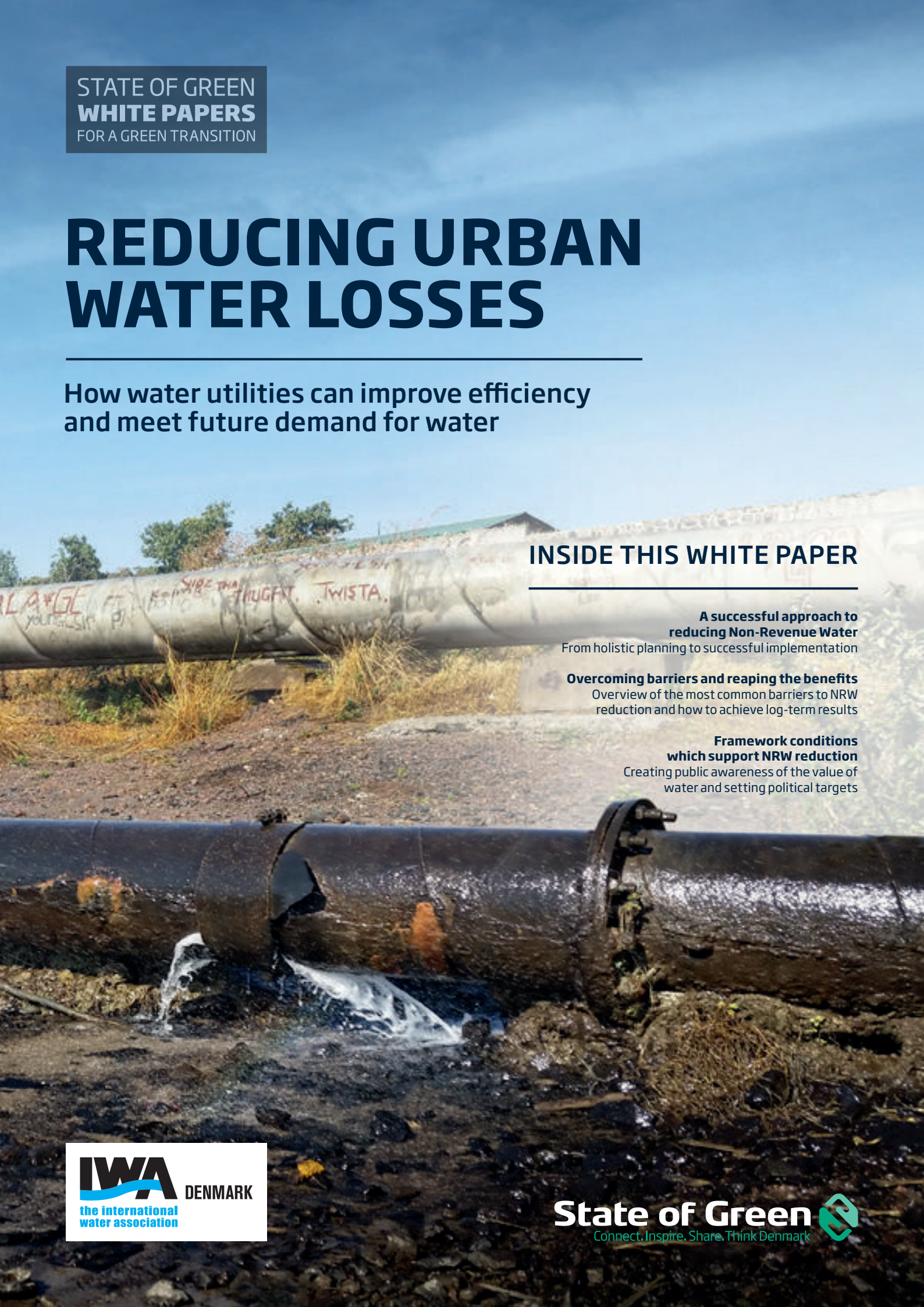
STATE OF GREEN
WHITE PAPERS
FOR A GREEN TRANSITION

REDUCING URBAN WATER LOSSES

How water utilities can improve efficiency and meet future demand for water



INSIDE THIS WHITE PAPER

A successful approach to reducing Non-Revenue Water
From holistic planning to successful implementation

Overcoming barriers and reaping the benefits
Overview of the most common barriers to NRW reduction and how to achieve log-term results

Framework conditions which support NRW reduction
Creating public awareness of the value of water and setting political targets

IWA DENMARK
the international water association

State of Green
Connect. Inspire. Share. Think Denmark

REDUCING URBAN WATER LOSSES
How water utilities can improve efficiency
and meet future demand for water

Version 3.0
Printed in January 2021

Front page photo
Photo: Klavs Høgh, NIRAS

Editor in Chief
State of Green Malene Bering Beitzel, mbb@stateofgreen.com

Technical Editors
EnviDan Jens Baadsgaard Pedersen, jbp@envidan.dk
NIRAS Klavs Høgh, kvh@niras.dk

Contributors
VCS Denmark Erling Nissen, en@vandcenter.dk
Grundfos Morten Riis, m.riis@grundfos.com
HOFOR - Greater Copenhagen Water Utility Trine Schreiner, trty@hofor.dk
HOFOR - Greater Copenhagen Water Utility Ole Skytte, olsk@hofor.dk
Kamstrup Anika Spindelmann, ANI@kamstrup.com
AVK Michael Ramlau-Hansen, mrh@avk.dk
Leif Koch Kroeze Andersen, ka@leifkoch.dk
Aarhus University/ WATEC Peter Henriksen, pet@bios.au.dk
Danish Environmental Protection Agency Kim Madsbjerg, kimad@mst.dk
Aarhus Vand Kurt Brinkmann Kristensen, Kurt.Brinkmann@aarhusvand.dk

Download this white paper
Download this white paper and other related publications at www.stateofgreen.com/publications

For more information
To order copies of this white paper or receive information about other related publications, please contact State of Green at info@stateofgreen.com

KYOTO PROTOCOL 2
No. 001
KLIMA-NEUTRAL TRYKSAG

CERTIFIED cradle to cradle
SILVER
PurePrint® by KLS
Produceret 100 % bionedbrydeligt af KLS PurePrint A/S

FSC www.fsc.org
MIX
Papir fra ansvarlige kilder
FSC® C022933

EXECUTIVE SUMMARY

Water consumption on a global scale is estimated to increase by up to 30 per cent by 2050 according to the United Nations. This will lead to an even greater supply gap for countries already facing water stress. In order to meet the future demand for water, a strong focus on efficient water management, utility operations and not least reducing Non-Revenue Water, is needed.

Today, 25-50 per cent of all distributed water globally is lost or never invoiced due to illegal connections, inaccurate billing systems, inaccurate metering, leakages, deteriorating infrastructure and lack of pressure management etc. This is known as Non-Revenue Water (NRW).

In addition to the environmental consequences, neglecting to reduce Non-Revenue Water has a serious impact on the financial viability of water utilities due to revenue losses and unnecessarily high operating costs. In order to reduce and maintain a low level of NRW, several aspects need to be addressed – from the initial planning phase to the day-to-day operations, as well as the use of high-quality installations and good workmanship.

Planning and prioritising NRW initiatives
The more water distribution data that is available and the better the management system is integrated, the easier it is to gain the necessary overview of NRW and subsequently prioritise investments. The first step in reducing NRW should therefore be to develop a holistic NRW master plan based on an analysis of the current NRW and the state of the water distribution network, which can then serve as the basis for upcoming investment plans and their projected returns.

Keeping NRW low throughout the operational phase
After implementation of a holistic NRW reduction programme, a continuous focus must be maintained on monitoring and optimising water distribution in order to maintain a low NRW level. Ongoing monitoring and pressure management are best conducted by breaking down the distribution system into smaller and more manageable units or District Metered Areas (DMAs).

The quality of installed components such as valves, pumps, pipes and meters etc. also play a key factor in reducing water loss. Since operating costs and repairs are often more expensive than the product itself, water utilities should focus on Total Cost of Ownership rather than simply the initial purchasing price of the products used.

Finally, carrying out a successful NRW programme requires commitment from all organisational levels as well as trained staff who work continuously to keep NRW at low levels.

Overcoming barriers and creating political awareness
Failure to successfully reduce NRW is often caused by an underestimation of the technical difficulties and the complexity of NRW management as well as a lack of understanding of the potential benefits of taking action. Subsidised water prices may also act as a barrier, as the costs and benefits of investing in NRW reduction will be less transparent.

Overcoming barriers to reducing NRW require attention and involvement from several stakeholders – from politicians to local customers – as well as new partnerships. The right framework conditions can create incentives for innovation and optimisation, as well as increase public awareness about the value of having a stable and efficient water supply.

"In a time where more and more cities and regions are affected by water scarcity, making sure the water that is abstracted also reaches the consumer is more important than ever"

Lea Wermelin, Minister for the Environment, Denmark

Drinking water is a valuable resource and in many countries, an unnecessary amount of water is lost on its way to the consumer. Denmark has been one of the driving forces in making sure water loss is a key focus area for the revised EU Drinking Water Directive, which is intended to secure healthy and clean drinking water for citizens of the European Union.

The United Nations' Sustainable Development Goal 6.1 aims to achieve universal and equitable access to safe and affordable drinking water for all by 2030. Reducing water loss benefits both the climate and the environment, as it reduces the amount of water which needs to be produced and in turn also reduces energy consumption stemming from the treatment and distribution of water. Non-Revenue Water also impacts the financial viability of water utilities (due to revenue losses and unnecessarily high operating costs) and ultimately communities, as their access to affordable drinking water comes under pressure.

In Denmark, we have instituted a number of measures to reduce the level of Non-Revenue Water, including creating an economic incentive for the water utilities to keep their Non-Revenue Water level below 10 per cent. At the same time, we have also worked hard to create awareness of the importance of water savings. As a result, we have managed to reduce our water consumption by more than 40 per cent since 1980. Doing so means that Denmark has achieved one of the world's lowest levels of NRW with a consistent national average of just 6 - 8 per cent compared to some parts of the world where NRW is more than 50 per cent.

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

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

INDEX

1. The importance of reducing Non-Revenue Water 6
Why Non-Revenue Water reduction should be top priority for all water utilities

2. A successful programme for reducing NRW 8
Achieving an efficient NRW reduction through a holistic approach

3. Planning and prioritising NRW reducing initiatives 10
Securing the right level and quality of information
for a successful NRW programme

4. Keeping NRW levels low throughout the operational phase 12
After implementation, continuous focus must be on monitoring
and optimising the water distribution

5. Smart Water Systems 16
Smart metering for leakage detection and consumption awareness

6. High quality equipment and workmanship 18
Skilled staff and high-quality equipment is key to low, stable NRW levels
and reduced investments in the long run

7. Barriers to successful NRW reduction 20
Why water utilities resist reducing Non-Revenue Water
instead of reaping the benefits

8. The importance of public awareness and political targets 22
Creating public awareness of the value of water
and political focus on NRW reduction

9. Securing future developments in NRW reduction 24
Innovation and new partnerships as drivers for continuous development

10. The true value of water 27
A Danish perspective on how we can shape our water future

1. THE IMPORTANCE OF REDUCING NON-REVENUE WATER

Why Non-Revenue Water reduction should be a top priority for all water utilities

In many cities 25-50 per cent of the distributed water is never invoiced to the customers. For growing cities, this is particularly problematic, as expanding the water distribution networks without reducing urban water losses effectively means expanding a cycle of inefficiency.

Non-Revenue Water (NRW) is the difference between the amount of water supplied into a distribution system and the amount of water that is billed to the customers. It comprises of:

1. **Apparent Losses**, also termed 'commercial losses', which are caused by inaccurate metering, data handling errors, theft and unknown connections.
2. **Real Losses**, also termed 'physical losses', which covers leakages from all parts of the system and overflows at storage tanks. Real losses are caused by poor operations and maintenance, combined with poor quality of the underground assets.
3. **Unbilled Authorised Consumption**, which is water used for flushing and firefighting, as well as water provided free to certain customer groups.

A more detailed description is found in the IWA Water Balance figure below.

Water is a scarce resource
Water consumption on a global scale is estimated by the United Nations to increase by up to 30 percent by 2050, which will lead to an even greater supply gap for countries already facing water stress. With a 'business as usual' approach and average economic growth, demand for water will outnumber known available freshwater resources by 40 per cent in less than 15 years. In order to meet future demand for water, it is therefore necessary to focus on efficient NRW management and achieving control of water loss today.

25-50 per cent of all distributed water is lost or never invoiced
Huge volumes of drinking water are never invoiced due to leakages, deteriorating infrastructure, inaccurate billing systems, deficient customer registration, inaccurate metering, reservoir overflow and illegal connections.

In addition to simply running a good business, reducing NRW is also of great importance for running a sustainable operation and a vital component in reaching the UN Sustainable Development Goal (SDG 6) on Clean Water and Sanitation. In the long run, neglecting to reduce NRW poses a threat to the development of the entire area. High levels of NRW will have a serious impact on the financial viability of water utilities and whole communities due to revenue losses and unnecessarily high operating costs. NRW thus directly affects the capacity of water utilities to fund necessary service expansions, conduct proper maintenance and invest in new technology.

In general, reducing NRW by half within one to two years is an achievable target for water utilities with water losses above 20 per cent. This entails an assumption that both a strategic focus and required funding are present. A reduction at that level will generate a considerable increase in annual income from billing, as well as reduced costs for water production.

A wide range of valuable benefits
An effective NRW programme will naturally focus on reducing urban water losses and increasing revenue but it can also lead to other important benefits for the water utility and its customers:

- Reduced stress on the available water resources, thereby allowing more people to be served by the same water source.
- Reduced energy consumption for abstraction, treatment and distribution, while still meeting the same demand for water as pressure is adapted to demand and smaller volumes of water will need to be treated and distributed.
- A more stable water supply, as improved performance will provide full pressure distribution 24 hours a day, 7 days a week.
- Better support for decision making and customer service due to new management systems.
- A strong basis for setting up a long-term rehabilitation and investment plan for the network.
- Improved water quality due to optimised water distribution, as chlorine content in the distributed water will be better controlled and the risk of pollution related to cloudbursts and periods with low pressure or vacuum will be reduced.

<table>
<tr><td rowspan="7">System Input Volume</td><td rowspan="2">Authorised Consumption</td><td rowspan="2">Billed Authorised Consumption</td><td>Billed Metered Consumption</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorised Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="5">Non-Revenue Water</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="3">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorised Consumption</td></tr>
<tr><td>Customer Metering Inaccuracies</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on Transmission and Distribution Mains</td></tr>
<tr><td>Leakage and Overflows at Utility's Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to the point of Customer Metering</td></tr>
</table>

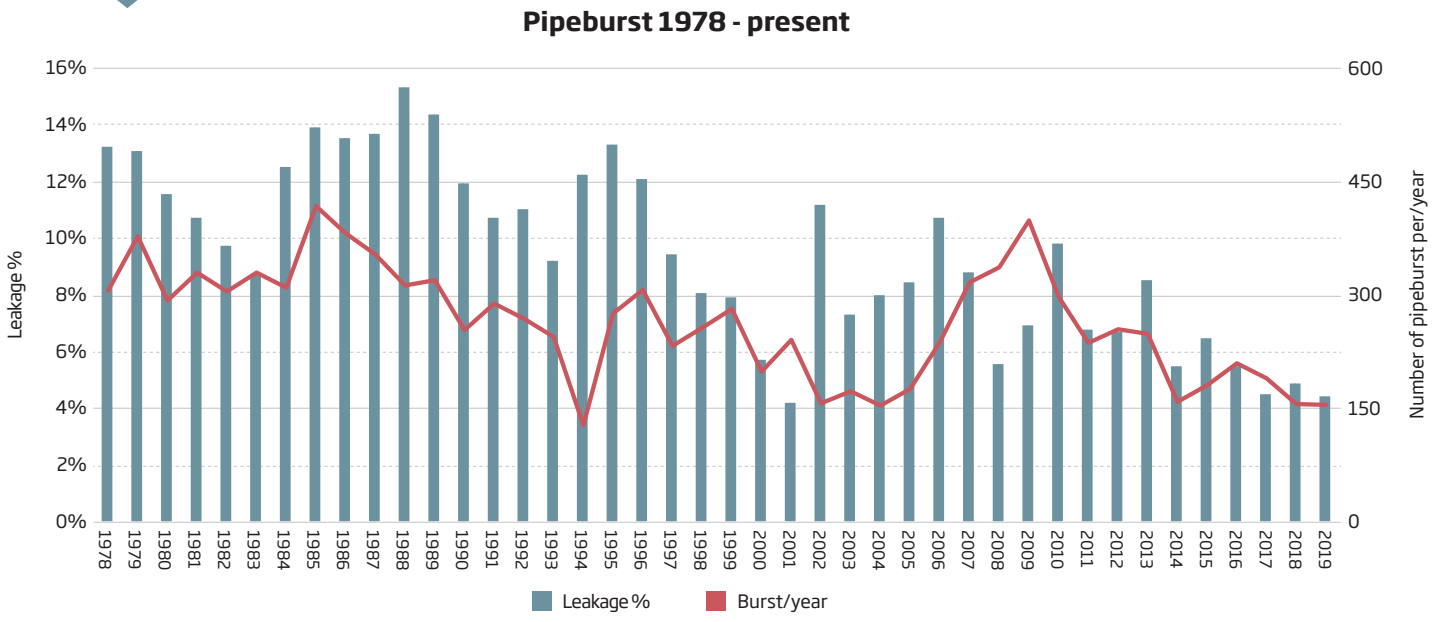
NRW strategy and Asset Management System reduces water losses, Aarhus, Denmark

For many years, NRW has been at the top of the agenda for Aarhus Water – the utility in Denmark's second largest city – and the NRW level has now reached a low of 4.5-5 per cent. A stringent focus on burst registration, rehabilitations plans and active leakage detection since the mid-1970s means that the utility has managed to reduce the number of annual bursts from 306 to 155 and water loss from 13 to 5 per cent, as depicted in the graph below. The objective for Aarhus Water is to maintain the NRW level at approximately 5 per cent.

To secure long-term success, Aarhus Water has also implemented a strategic pipe replacement program using intelligent tools such as machine learning, which enables the prioritisation of pipe replacement in the distribution system. The prioritisation is based on risk parameters and cost-benefit analyses in order to meet the objectives in their NRW strategy. This program will be further developed to complement the Asset Management System in order to perform a data-driven risk assessment on the distribution system.

To meet the objective of maintaining a low NRW level, it is important that the NRW strategy can ensure effective maintenance by active leakage detection and find the right balance between selective pipe replacement and leak detection. In addition to implementing the asset management system, high quality construction work, pressure management, monitoring DMA night flows and new innovative methods will be developed, which will benefit and improve current work.

Courtesy: Aarhus Water



The increase in the total NRW between 2002 - 2005 followed by the reverse development in the coming three years was due to a test period without active leakage control. The increased number of bursts in this period demonstrates the importance of having a sound strategy for active leak detection.

2. 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 investments. 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 installing new components include the length and the scope of the warranty, Total Cost of Ownership, energy consumption 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.

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

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

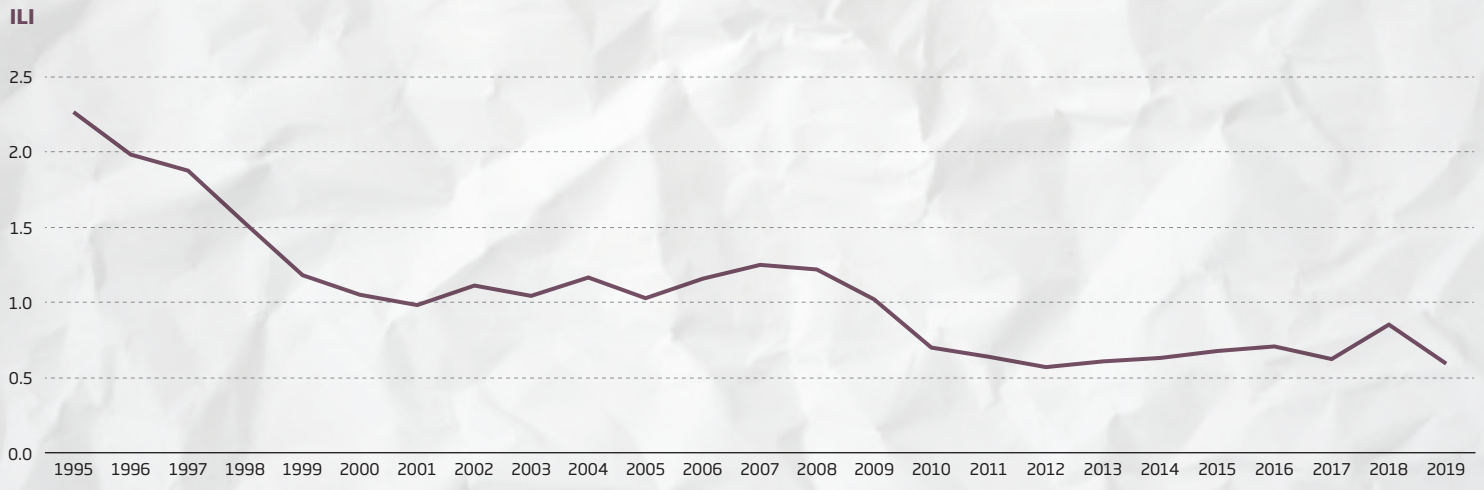
Implementing comprehensive NRW reduction plan, State of Johor, Malaysia

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 rehabilitation 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.

Courtesty: Ranhill SAJ Sdn. Bhd. and NIRAS



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

In the city of Odense, the home town 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.

Courtesy: VCS Denmark

3. PLANNING AND PRIORITISING NRW REDUCING INITIATIVES

Securing the right level and quality of information for a successful NRW reduction programme

Water utilities with low quality installations, poorly maintained infrastructure and no leakage management systems in place easily lose up to 50 per cent of the water produced. To reverse this development, the first step should be to conduct a water audit based on all available data and develop an NRW master plan for upcoming investment plans and their projected returns.

It is crucial that an NRW reduction programme is managed 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. The first step is to conduct a water audit that includes an assessment and analysis of the performance of the water distribution system as well as identifies and quantifies areas for improvements. The outcome of the water audit is then used as essential input into the NRW master plan that will serve as the basis for upcoming expansions, rehabilitations and investment plans as well as their projected returns. With respect to NRW reductions, the most important outcomes of the water audit are:

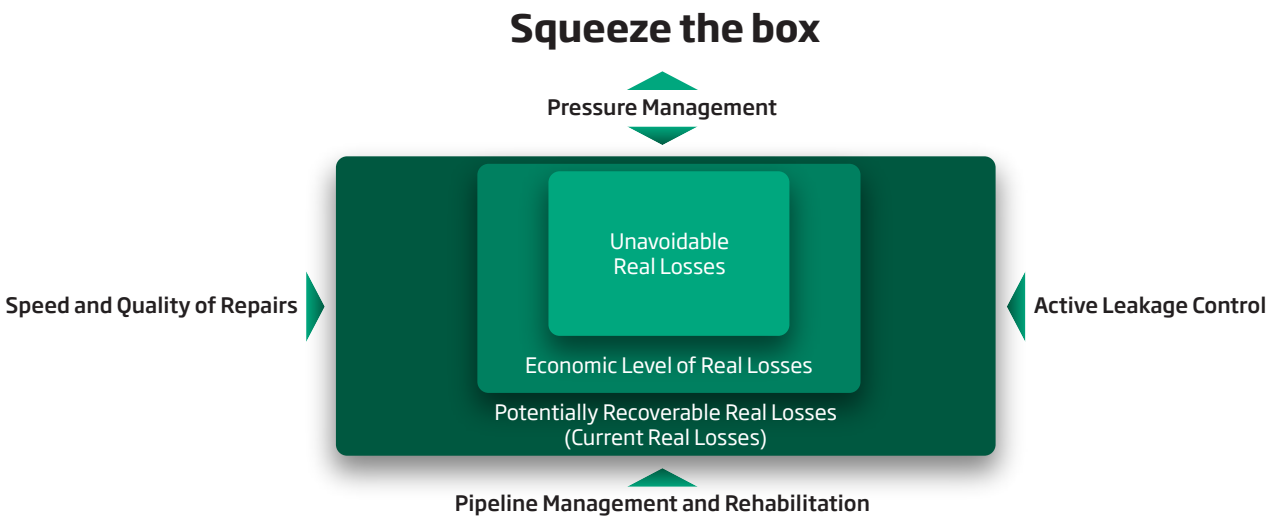
- The IWA water balance, including a baseline for the NRW level.
- A component analysis of the IWA water balance that details the relation and magnitude of the elements that make up the total NRW, including dividing the water losses into real losses and apparent losses.

The water audit should be implemented as a recurring (annual) event to continuously quantify the effects of the implementation of the NRW master plan on the water balance, and thus enable the utility to add any required modifications or corrective actions to the master plan. Once completed, the NRW master plan will provide the following information:

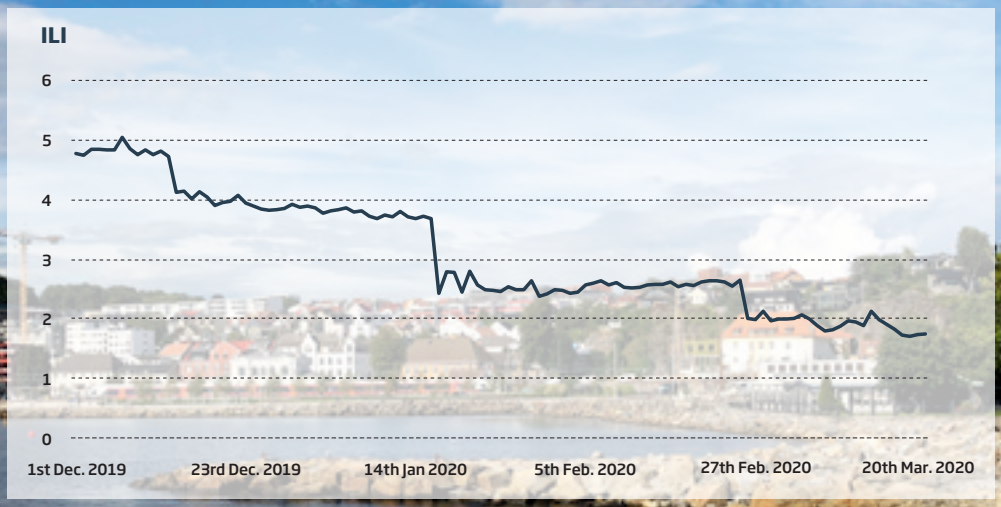
- A prioritised list of activities and investments to strengthen the NRW reduction programme.
- Calculation of the Economic Level of Leakage (ELL) based on cost-benefit calculations. See the illustration below for reference.
- Mapping of root causes for real losses and apparent losses respectively, with a clear distinction between the sub-strategy, activities and targets for each.
- Activities developed on the basis of cost-benefit calculations such as active leakage control, district metering, pressure management, meter replacement etc.
- A strategy for the implementation and development of the Information Communication Technology (ICT) systems including GIS, SCADA, modelling tools and management systems.
- Design and implementation of District Metered Areas (DMA) and Pressure Management Areas (PMA) based on hydraulic modelling.
- Budgets for the NRW reduction activities, the financial benefits and specific ROI.

Ensuring the highest return on investments

The key is to identify where the returns on investment will be highest. Economic Level of Leakage (ELL), which is calculated as part of the master plan, will provide the answers. It takes into account cost-benefit analyses relating to each element of NRW, as provided from the water audit. It also takes into account the forecasted influence of the reduction in NRW on future investments in treatment plants, raw water abstraction, pumping stations etc. as well as the potential effects on revenue generation and energy savings.



Standard illustration of potential reduction of real losses through four types of activities; pressure management, speed and quality of repairs, active leakage control and pipeline management and rehabilitation.



Fast track to successful NRW reduction in Larvik, Norway

The City of Larvik has a customer base of 39,000 people. Larvik is also a holiday destination, and during summer of 2018, the municipal water treatment plants had difficulty meeting demand. Larvik has several pressure zones, altitudinous reservoirs and pumping stations. The distribution system has eight major districts, subdivided into 20 DMAs with 35 district meters.

The city decided to implement KeyZones monitoring system that consists of intensive data collection and systematisation. Operational in 6 weeks, the system gathered smart meter data from the past 2 years to reference for initial analysis of the KPIs. At the handover of the KeyZones system, initiatives and methods for active NRW optimisation were selected, based on the DMAs with the most potential for NRW-reduction.

A 20-25 m^3/h leak with six months runtime was found after a week. Another leak of 35-40 m^3/h, with 5 months runtime was also identified. The investment costs for implementing KeyZones was, despite the low water price, recouped through the repair of those leaks. Further initiatives such as changes to pressure zones were implemented, enabling Larvik to reduce the ILI from 5.0 to 2.5, within 6 months.

Courtesy: City of Larvik and EnviDan

New technology reduces NRW to less than 10 per cent in just one year, Ail Ain, Abu Dhabi

The city of Al Ain in Abu Dhabi is working towards a more sustainable water supply. The city's utility company, Al Ain Distribution Company (AADC), is implementing a Water Network Management System (WNMS), based on the LEAKman concept, that will contribute to a more connected and efficient operation of the distribution network for drinking water, with focus on the reduction of NRW.

The WNMS enables AADC to identify and prioritise NRW improvement initiatives faster and more effectively than before. The water distribution network in the city consists of 113 District Metered Areas (DMAs). A key component in the new monitoring solution is HOMIS – a performance monitoring system developed by NIRAS. HOMIS collects data from all operational systems to calculate and report online performance indicators. In a successful pilot project in 2015, NRW levels were reduced to less than 10 per cent in the most vulnerable DMAs of the city – all within the space of a single year. AADC is now in the process of a full-scale implementation of HOMIS to cover all 113 DMAs.

Courtesy: NIRAS and AADC - Al Ain Distribution Company

4. KEEPING NRW LEVELS LOW THROUGHOUT THE OPERATIONAL PHASE

Following implementation, continuous focus must be on system maintenance as well as on monitoring and optimisation of the operations.

The NRW programme has to be maintained during the operational phase. This requires daily focus on both maintenance as well as operational efforts such as pressure management, leakage monitoring and fast and efficient leakage repair. This way, it is possible to keep a low NRW level while also achieving other benefits such as energy savings, improved drinking water quality and high customer satisfaction.

Best practice NRW management is based on the principle of breaking down the distribution system into smaller and more manageable units known as District Metered Areas (DMAs), where the flow balance can be monitored for each DMA. Ideally, a hydraulic model is used to optimise the design of the DMAs, where several considerations are applied such as minimum detectable leak size, pressure balancing across the DMA, grouping of customer categories and security of supply. The system may be further developed by installing noise loggers for fast detection of new bursts and by establishing active pressure management. This can be done in each DMA or in groups of DMAs, grouping the DMAs into Pressure Management Areas (PMAs). Ideally, this will also be based on hydraulic modelling.

Pressure management is implemented by use of pump or valve controls, depending on whether the specific PMA or DMA is to be subject to increases or reduction in pressure. As the demand for water varies widely throughout the day, controlling the inlet pumps or valves supplying the individual PMA/DMA will reduce the existing background leakage, frequency of new pipe bursts and optimise energy usage.

Integrating NRW into day-to-day operations

Controlling NRW is a long-term and ongoing effort. Focus during the operational phase should continuously be on:

- Conducting annual water audits to identify potential areas for improvement and include these in the NRW master plan.
- Regular analysis of the NRW level based on the water balance in each DMA.
- Optimisation of the DMA performance based on ILI and ELL for each DMA.
- Installation of new technological advances, e.g. smart customer meters to ensure a continuous improvement and expansion of reliable data from the distribution system.
- Implementation of active leakage detection in hot spot areas based on real-time monitoring, online NRW analyses and use of acoustic noise loggers.
- Fast response times for emergency leakage repairs based on an online alarm system.
- Training and capacity building to improve the skills of employees.
- Pipe rehabilitation and replacement based on strategic plans targeted at prioritised areas.

Ongoing rehabilitation programme

In addition to the daily NRW management, successful NRW reduction requires a long-term rehabilitation strategy for network maintenance and rehabilitation. Water distribution networks are often constructed over many years and continuously expanded and adjusted to meet the requirements of increased urbanisation. New regulatory requirements for drinking water supply are imposed on the water companies, new technologies and more efficient construction methods are developed and the benefits in upgrading to the best available standards are often quite significant.

Leakage monitoring and control

Using online water meters (smart meters) at customer level means that the operators can monitor the water balance for each DMA with a much higher frequency, and much more precisely, compared to the traditional setup with monthly or annual readings of the customer meters that are conducted manually. The first Danish water utilities to have implemented smart customer meters are experiencing huge benefits in terms of shorter response times on leak detection and leak repairs.

Water utilities serving areas with vulnerable pipes that are especially prone to bursts are adding permanently deployed acoustic noise loggers, with automated data collection, as an additional technology that allows pipe burst to be registered, reported and localised within 24 hours.

Building a sustainable water supply with smart metering in Shirpur-Warwade, India

Shirpur-Warwade is the first town in India to implement smart water meters and automatic meter reading systems. Previously, customer were billed at a yearly flat rate, as the council had no means with which to track the water consumed at individual households. Citizens in drought prone areas experienced intermittent water supply, which led to improper and excessive water use. The municipality therefore created the goal of establishing a 24/7 water supply and introducing fair billing.

With data from 13,500 smart meters, the daily water supply has been reduced by 33 per cent. Time spent on the billing process has gone from two months to five days. The transition was challenging due to installations in narrow, dense housing infrastructure, as well as risk-aversion on behalf of the inhabitants. The flexible mountain options with the ultrasonic meters, alongside training to build trust and awareness between the council and customers, solved the challenges. By converting the previously billed un-metered water into billed metered water, the town is now collectively committed to saving water and has reduced daily water consumption from twelve to eight million litres.

Courtesy: Kamstrup A/S

Pressure management reduces NRW by 30 per cent in Montodine, Italy

The Padania Acque Gestione S.p.A water company in Montodine, Italy was losing water and using more energy than necessary in its distribution network. The total network covers 10.3 km of pipes serving 6,580 inhabitants. Approximately 275,000 kWh of energy was used to distribute 670,000 m^3 of water annually.

To minimise this, the water company decided to use Demand Driven Distribution (DDD) controller and pumps to monitor and adjust pressure. Pressure transducers were installed at the ends of the water distribution network, where pressure values are measured and then sent to the DDD controller via a GSM network. The controller ensures optimum pressure, and by gradually ramping-up and ramping-down pressure, avoids sudden momentum changes in the pipes.

The pressure recorded in the network has remained steady at around 3.0 bars, without any limitation of service to users. An evaluation based on the minimum night flow estimates a reduction in real losses of about 25,000 m^3/year. In terms of the total losses of the distribution system, this results in a reduction of approximately 30 per cent NRW and energy savings of 17 per cent.

Courtesy: Provas and Grundfos

AGE OF PIPELINES IN COPENHAGEN:

Keeping NRW low through good management in Copenhagen, Denmark

HOFOR - Greater Copenhagen Water Utility supplies around 700,000 customers in Copenhagen with drinking water. The residents of the Danish capital consume approximately 31 million m^3 water annually.

The distribution network has a high average age, as 20 per cent of the network pipes are more than 100 years old. Despite this, the utility managed to keep the NRW level at just 5.6 per cent in 2019. Analysis shows that the cast iron pipes laid before 1945 have a low burst frequency. The high quality of these pipes, representing 50 per cent of the network, is key to the low NRW level.

The real water loss in 2019 was 5.0 m^3/km/day and the Infrastructure Leakage Index (ILI) was 2.6. A low NRW value is achieved through appropriate planning and maintenance. The water loss has been kept low through systematic leakage detection, where the system is manually surveyed in a three year cycle, combined with appropriate rehabilitation planning. The network rehabilitation planning is based on a methodical selection of the pipes that are most prone to bursts. The selection considers the pipe material and age as well as leakage and burst history.

To improve the balance between replacements and maintenance, HOFOR is adopting an asset management and a management information system. The systems will also help optimise the periods between active leakage detection, aiming to achieve a higher degree of performance based asset management.

Courtesy: HOFOR - Greater Copenhagen Water Utility

5. SMART WATER SYSTEMS

Implementing modern ICT tools to assist with NRW performance monitoring and reporting

The latest technology advances within communication platforms and smart devices has opened the door to a new generation of innovative tools and techniques that will set new standards for NRW management and water loss control.

Today, most water utilities in Denmark are highly digitalised; meaning that key administrative, planning, and operational systems are digitised and most importantly - the data is stored in open (non-proprietary) databases. This means that that the data can be utilised across the water utility to increase the level of knowledge of performance.

In addition, a massive development of new communication platforms such as IoT, 5G etc. have taken place recently, and smart devices (AMR, deployed noise loggers etc.) mean that more data is being collected than ever before. Thereby the foundation is laid for many utilities to operate as a Smart Water Network.

The principles of SWAN

The Smart Water Networks Forum (SWAN) has defined a 5-layered model that describes best practice for any water utility seeking to transform into a Smart Water Network, improving efficiency, durability and reliability of the physical distribution network.

Referring to the figure below, the basis of a smart water system is made up by:

- Adding smart devices to the sensing & control layer,
- Adding new technologies to the data collection & communication layer,
- Expanding the data management & display layer to handle the increased amount of data, and finally,
- Adding the new layer data fusion & analysis where all data can be accessed across all systems.

The top layer will include advanced data analysis tools that may use historical as well as real-time data to conduct advanced reporting, forecasting and optimisation of the operations. Various algoritms (including artificial intelligence and machine learning) are used, in order to aid decision making and improve drinking water distribution, reduce water and energy consumption.

Building a smart water system

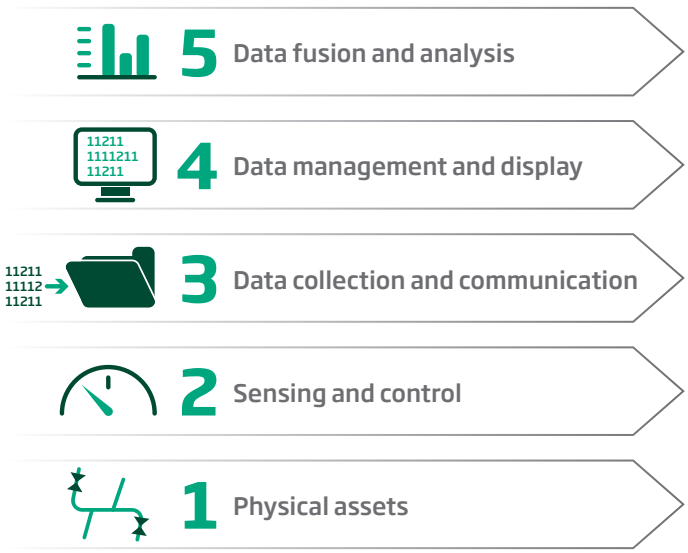
A smart water system consists of multiple components such as smart meters, intelligent pumps, intelligent valves, deployed noise loggers and much more.

As an example, pressure management is implemented via the use of intelligent pumps or intelligent valves, depending on whether the specific area (PMA or DMA) is to be subject to a pressure increase or a pressure reduction. In extreme cases, some areas may be subject to a combined solution to cater for all operational scenarios. As the demand for water varies widely throughout the day, controlling the inlet pumps or valves supplying the individual area will reduce the existing background leakage, frequency of new pipe bursts and optimise energy usage. This is implemented by regulating the pressure supply to a level that secures the minimum guaranteed pressure at the critical point, thus securing an adequate pressure at each customer location throughout the day.

Further, several Danish water utilities have implemented a number of ICT tools to support strategic rehabilitation planning of the transmission and distribution network. These tools use input from all available systems to support water utilities in executing the following objectives:

- Long-term investment planning and updates on budgets
- Continuous overview of rehabilitation projects
- Prioritisation of rehabilitation activities
- Cost optimisation of the rehabilitation sequencing
- Documentation of rehabilitation progress and strategy

Using a combination of spatial data analysis, machine learning and cost optimisation enables water utilities to establish a long-term holistic plan for their NRW interventions and improvement initiatives. The effects of these are continuously monitored and reported back to the operational management and used for prioritising the ongoing active leakage control activities in the network.



Smart Water Networks is layered, each layer having explicit functions as described and with interconnection between the adjacent layers. Source: www.swan-forum.com

Reducing water loss with acoustic leak detection in Söderhamn Nära, Sweden

Every year 400,000 m^3 of water was lost on its way to Söderhamn Nära's customers. This equates to water losses of 20 per cent. To reduce that number, the utility started rolling out a new smart metering solution with integrated acoustic leak detection. Previously, the hunt for leaks had been a time-consuming and expensive task that required going from valve to valve to listen for leaks, shutting off areas one by one to verify assumptions.

Today, their smart meters flowIQ® 2200 and analytics platform, Leak Detector, let them identify areas with potential leakages, located both before and after the meter. The team can then verify the leaks and repair them. One hour after the first meter was installed, an alarm was registered, and a leak identified on a service line. Over a six-month period, approximately 100 leaks were detected at the end customer, as well as two leaks in service connections. Söderhamn Nära's efforts are now more targeted and resource efficient. They are now able to warn their customer of leaks and guarantee more precise invoicing.

Courtesy: Söderhamn Nära and Kamstrup A/S

6. HIGH QUALITY EQUIPMENT AND WORKMANSHIP

Skilled staff and high-quality equipment are key to low, stable NRW levels and an extended lifetime for infrastructure investments

In addition to skilled workmanship, the use of high-quality equipment for infrastructure installations is strongly recommended. Focus should be on low cost of ownership, long warranty times, low energy consumption and reliable online measurement equipment.

The key success factor in achieving and maintaining low levels of real NRW losses in the long run is the reliability and stability of installed components (pipes, valves, pumps and meters etc.). Together with the quality of workmanship in installation and operation, choosing high quality products is essential. Since the value of lost water and the cost of repairs often are far more expensive than the product itself, the expected operating reliability and the quality of installed products should have highest priority in the selection criteria of the purchasing process. These factors should be considered in tandem with the cost of ownership. Other important factors in selecting products are; product efficiency, customer training, options for technical advice and service.

Reducing physical losses by minimising leakages in pipes or valves

Water loss adds significantly to operating costs. Leakages can occur as leaks in the pipes, valves or joints, e.g. caused by valves that are not drop tight or have worn out stem sealing.

Once equipment has been installed below the ground as a part of the distribution system, it is very difficult to control the valves, pipes or other installations. It is important that all equipment and installations are of high quality to ensure that they will function properly for many years. Only quality products with a long warranty, reliable and durable function should be selected and it should be based on the principals of Total Cost of Ownership and not simply on the initial purchasing price. A generally accepted norm is that the purchasing cost for a pump is only 5 per cent of the total cost of the pump's lifetime, where 10 per cent accounts for maintenance cost and the remaining 85 per cent goes to energy costs related to operating the pump.

High-quality materials ensure a long lifespan

PE pipelines with an estimated durability of 80-100 years are used for all new water distribution networks and service pipes in Denmark. Welding and making joints of the PE pipes must be carried out by well-educated staff in accordance with quality standards to ensure a correspondingly long network lifespan. By choosing high-quality, shut off valves, leakages from the valve itself can be avoided. Gate valves with high-quality rubber gaskets ensure that the valves are 100 per cent drop tight. Valves, pipes and joints must all be made of corrosion free materials.

Skills and well-trained staff

NRW reduction is not just a technical issue. Carrying out a successful NRW programme and achieving strong results require committed management and trained staff that continuously work on maintaining low NRW levels. A comprehensive re-evaluation of the water utility's strategy and priorities is necessary to implement learnings along the way. The management level must prioritise the activities of the NRW programme and the benefits of purchasing equipment with high accuracy, reliability and low Total Cost of Ownership.

In order for the water utility to adapt and reap the full benefits from an NRW management system and new smart water technology, training and technology transfer programmes are performed in collaboration with Danish water utilities that are designed to aid in achieving continuous positive results in NRW reduction. The technical staff should receive training on how to use tools such as GIS, hydraulic models, leakage detection equipment, noise loggers, online monitoring systems and smart meters. The training programme should include staff at all levels; from the planners to the craftsmen, who all need to understand the necessity of following the specific procedures and QA systems.

Efficient water supply management reduces critical water losses in Tbilisi, Georgia

Georgian Water and Power (GWP) were experiencing water losses of around 70 per cent. Serving approximately 507,432 customers in the mountainous city of Tbilisi, the GWP water distribution network consists of 3,600 km pipes and spans five vertical zones.

To obtain a more efficient water supply, optimising both electricity and water usage, GWP decided to invest in 500 high-quality pressure-reducing valves from AVK. By avoiding water hammer occurrences and managing pressure created from reservoirs situated at heights, GWP reduced the rate of bursts and leakages.

Upon installation of the first 235 pressure-reducing valves, electricity use was lowered by approximately 10 per cent and pumped water reduced by 27,740,000 m³/year, which is a reduction in NRW of 50 per cent. In addition to electricity and water savings, the pressure-reducing valves also reduce operational and maintenance costs and have reduced pipe bursts by approximately 25 per cent.

Courtesy: AVK International A/S, Georgian Water and Power Ltd.

Collaborating for proactive leakage detection

Within seven years, HOFOR - Greater Copenhagen Water Utility has lowered their water losses from 10 to 5 per cent. This has partly been achieved by employing a strategy of proactive leakage detection as well as using experts for support.

Continuous leakage detection performance is key to maintaining expertise and difficult to gain when leak frequency is low. Therefore, HOFOR collaborates with leakage detection experts on issues such as getting and keeping water losses at a low level, assistance with leakages that in-house staff are unable to detect but are revealed by night time flows, training of in-house staff for triannual manual surveying and consultancy advice on the most applicable equipment and staffing for a specific NRW goal.

As a trial, approximately 200 noise loggers that are connected to the online monitoring software ALMOS LEAK were installed in an area of Greater Copenhagen where no prior leaks had been detected. Within two days, the system detected a leak. It was left unrepaired for a week to access potential costs, which would have run up to EUR 280,000 before the next triannual manual surveying.

Courtesy: Leif Koch and HOFOR

7. BARRIERS TO SUCCESSFUL NRW REDUCTION

Why water utilities resist reducing Non-Revenue Water instead of reaping the benefits

NRW is a challenge most water utilities understand excellently, but only a few are successful in reducing it. Much of the failure is due to an underestimation of the technical difficulties and the complexity of NRW management, along with a lack of understanding of the potential benefits of taking action. Reducing NRW is not a project, it is a continuous process.

Reducing NRW should have highest priority for every water utility, however it can seem that there exists a state of inertia in many water utilities despite high NRW levels. Some of the most common reasons for this situation and lack of action might be:

1 **Lack of political awareness:**
In many places the value of drinking water is taken for granted and as a result lacks both political focus and priority. Drinking water is often priced very cheaply because water prices are subsidised by governments, either directly or indirectly through low energy prices.

2 **Inaccurate data:**
Having access to reliable data is crucial, as inaccurate meter readings etc. may lead to wrong decisions. In some places, the utility might also face problems with customers tampering with their water meters.

3 **Corruption leads to inefficient NRW projects:**
Corruption on several levels may result in huge amounts of money being spent on pipe replacement projects with little or no impact on the NRW level.

4 **Focus on purchasing price rather than Total Cost of Ownership:**
Tenders and purchasing decisions focus solely on the acquisition price of e.g. new equipment rather than looking at the cost of ownership throughout the lifespan of the products. This will often result in poorer solutions and increase the need for replacements relatively quickly.

5 **Employee performance appraisals do not support NRW reduction:**
Admitting excessive levels of NRW can be embarrassing for water distribution managers and employee performance appraisals might not encourage seeking better accuracy in NRW reporting, which is necessary to improve the water utility's NRW level.

6 **Fear of negative image:**
In areas which are suffering from droughts and where the water utility has asked customers to reduce their own water consumption, it may be viewed as problematic to admit to excessive leakage problems.

7 **NRW is not connected to overall sustainability goals:**
There is often little perceived connection between NRW management and the utility's overall sustainability or climate change goals.

Reaping the benefits of reducing NRW
There are many benefits to be reaped from adopting and successfully implementing a NRW reduction programme. Reducing urban water loss can delay the need for additional water resources in cities with a growing population, as up to 30 per cent more inhabitants can potentially be served from an existing resource by making distribution systems more efficient. Any investments in the utility's water supply, including new intake and treatment plants, should therefore be considered as opportunities to reduce NRW down to the ELL.

Considerable energy savings
If 25 – 50 per cent of the water produced is lost through leakages and never reaches end customers, it also means that the energy used to treat and distribute the water is wasted. It is possible to realise considerable energy savings, as a typical NRW reduction programme also ensures more stable water pressure throughout the system, which in turn increases energy efficiency even further.

Higher revenues
It is estimated that the apparent loss caused by inaccurate metering and data handling errors etc. typically makes up 25–75 per cent of the total NRW. A high NRW can therefore seriously affect the financial viability of water utilities as a result of lost revenues. The costs savings and increased revenues gained from reducing NRW through efficient management can therefore be transformed into larger working funds for the utility, securing its future efficiency and development for the benefit of the entire region.

Sustainable change requires broad stakeholder engagement
Overcoming barriers to reducing NRW requires attention and involvement from many different stakeholders – from politicians to local customers. This will be described further in the next chapter.

Oslo fights water losses with a new state-of-the-art Leakage Management System, Norway

The Norwegian capital is a growing city and with this arises a pressing need to secure the city's future drinking water supply. Currently, 35 per cent of the drinking water is lost on the way from the waterworks to the customers. To increase water security and reduce water losses, Oslo Water launched an ambitious masterplan in 2018 that aims to reduce Non-Revenue Water (NRW) to 20 per cent by 2030.

Key elements of the plan are an implementation of Aquis – an online Hydraulic Modelling System – as well as the Holistic Management Information System (HOMIS). In 2020, project progressions have provided Oslo Water with a real-time hydraulic overview of more than 1,550 kilometres of water supply pipelines, which by using Aquis, have been divided into 53 District Metered Areas (DMAs). Through online hydraulic simulations, all DMAs deliver valuable results for active leakage control as inputs to HOMIS, where leakage location teams use the overviews with more than 20 Performance Indicators (PIs) per DMA to analyse and prioritise their efforts.

Capacity building with specialists alongside preconfigured hydraulic dashboards for NRW investigations and continuous online monitoring of PIs in HOMIS provide Oslo Water with the necessary tools to reach the 20 per cent goal by 2030.

The next steps of the NRW plan are to install and include more technologies such as pressure management to reduce leakage flow, noise loggers for fast detection of non-surfacing leaks and bursts, and smart meters for more accurate water balances.

Courtesy: NIRAS Denmark, NIRAS Norge and Municipality of OsloMunicipality of Oslo

8. THE IMPORTANCE OF PUBLIC AWARENESS AND POLITICAL TARGETS

Creating public awareness of the value of water and political focus on NRW reduction

It requires extra attention and improved service to convince consumers that water has a value and that the water bill is a sign of priceless and essential needs. Consumers must be educated to appreciate the value of having a stable supply of safe drinking water and to treat the supply with respect. This requires both political attention and political prioritisation.

The awareness and understanding of the value of water is very limited in many countries. Often, the price of water does not cover the actual investment and operational costs. Political focus and priority from government institutions is required in order to make consumers aware of the value of having a stable supply of clean tap water. Subsidising the water price should only be used to support the poorest in having access to drinking water and the price for water should reflect the actual costs.

In many places, the apparent loss poses the biggest challenge and it takes a change in consumers' mindsets to bring it down. NGOs and anthropologists can be involved in changing people's mindset and behaviour when it comes to drinking water as well as their understanding of how consumer payment for water is necessary to ensure sufficient funding for the development of a sustainable water supply with clean and safe water.

Economic growth can go hand in hand with reduced water consumption

Denmark has shown that economic growth and decreasing resource consumption are not mutually exclusive; they can in fact go hand in hand successfully. Danish water consumption has decreased by 40 per cent over the last thirty years while the country's GDP has increased by 75 per cent. Continuous awareness about the importance of saving water together with tax incentives have resulted in water consumption figures that are acknowledged worldwide. In 2019, water consumption in Denmark per capita on average was 101 l/day. The total price for water supply and wastewater treatment is an average of EUR 9.5 per m^3, meaning that the price is also a strong incentive to reduce consumption.

The national average for non-revenue water has been reduced to 6.5 per cent due to intensive focus on the problem. Government regulations have motivated water utilities and technology providers to develop new, cost-efficient leakage monitoring technologies and leakage management systems. The highly efficient Danish water distribution system can also be reflected in the fact that the ILI in 2019 was on average 0.6.

Economic incentives to reduce NRW

Economic incentives are important drivers for affecting behavioural change. For decades, politicians and decision makers in Denmark have understood that public regulation and taxes are important and effective tools for behavioural change. For more than 25 years, regulations have stipulated certified metering of all water consumption at the consumer level in Denmark. Furthermore, Danish authorities impose high penalties on water utilities that do not reduce their NRW level to less than 10 per cent through extra taxes on water lost.

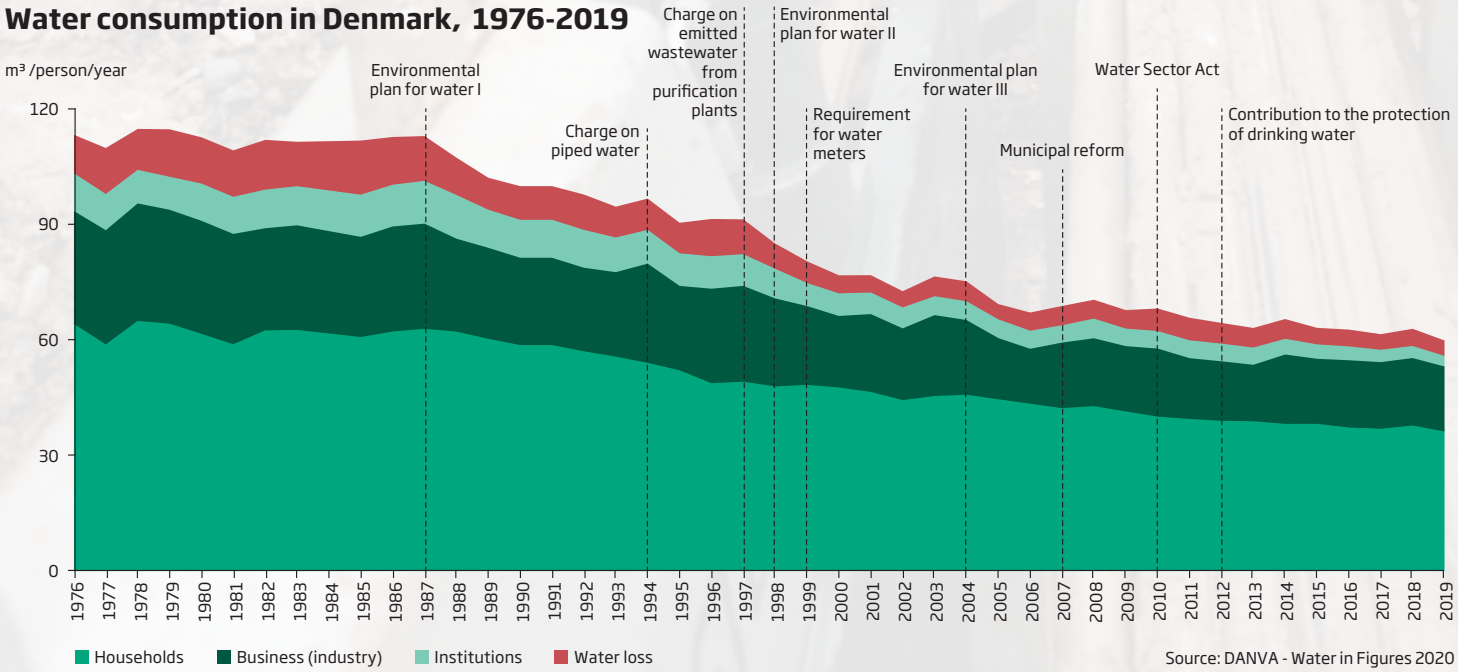
Benchmarking for efficiency

Benchmarking can also be a tool for water utilities to identify performance and optimise their respective work processes and methods by learning from best practice examples of their cohort. Each year, the Danish Water and Wastewater Association (DANVA) collects and publishes performance data – including NRW data – from more than 130 Danish water utilities in an annual benchmarking report, which allows each water utility to learn from its peers.

Coupling NRW to the climate change agenda

Climate change mitigation and reduction of CO_2-emissions is increasingly attracting political attention across the globe. It therefore makes sense to address reduced energy consumption as a positive spillover effect of NRW reductions when considering the efforts and expected results of an NRW programme. Reducing NRW will dramatically change the operation of the water distribution, as the change in pressure and closing of leaks in particular can lead to considerable energy savings. In addition to reducing CO_2 emissions, reducing NRW contribute to achieving the UN Sustainable Development Goals. This is especially so in the case of SDG 6: Clean Water and Sanitation, however also in regards to several other of the SDGs such as SDG 11: Sustainable Cities and Communities, SDG 3: Good Health and Well-Being as well as SDG 12: Responsible Consumption and Production.

Water consumption in Denmark, 1976-2019



Source: DANVA - Water in Figures 2020

Data Source: 1976-1998: Master project: Modelling water demand by Nana Sofie Aarøe – data for 14-30 companies.
1999-2019: Data from DANVA's calculations for Water in figures – data from 33-116 companies

9. SECURING FUTURE DEVELOPMENTS IN NRW REDUCTION

Innovation and new partnerships as drivers for continuous development

State-of-the-art technology and best available solutions are continuously developed based on product innovation, smarter ways of working and better integration of different solutions. New innovations can contribute to lowering NRW and improving the efficiency of the water distribution.

In Denmark, great emphasis is placed on research and innovation programmes to ensure continuous improvements in NRW projects. Companies working in the water sector, water utilities and research institutes are encouraged to work together on developing new and innovative technologies and solutions for both the Danish and the international market.

The Danish Eco-Innovation Programme

Experience shows that innovation is best achieved when the competencies of different stakeholders are exploited in a close interplay between companies with complementary products or services as well as researchers and water utilities. Bringing different stakeholders together in binding strategic partnerships has therefore boosted innovation in the Danish water sector.

Following a request from a unanimous Danish parliament, the first Eco-Innovation initiative was launched by the government in 2006. The primary aim of the programme is to promote new and efficient environmental solutions, strengthen green exports and create more jobs. The secondary purpose is also to boost and strengthen cooperation between companies, research institutions and partners in the EU within the field of environmental technology. The programme and the associated funding scheme are run by the Ministry of Environment.

Strong tradition for collaboration across the water sector

Danish water utilities actively participate in innovation projects as a way to improve their performance and become more efficient in delivering fresh drinking water to their customer. As a result, they are generally very open to cooperating with other stakeholders in the water sector on developing new and improving existing practices and technologies. This could for instance include advanced use of software, data collection and communication technology combined with smart meters to collect important information about consumption in order to optimise their water supply to the network and save energy.

One example of this type of technological development is the case of Danish water utilities who are implementing smart water meters and noise logging tools in order to collect more reliable data from the distribution system and thereby manage their NRW even better. The data from the smart meters, which is collected both at the customer end and in strategic locations in the distribution system, provide water utilities with more accurate daily NRW levels in each DMA; enabling them to optimise their NRW activities on a daily basis. The use of Artificial Intelligence (AI) and Big Data technology has started a revolution in data collection and analysis that makes it possible to predict pipe leaks or bursts and localise them instantly, meaning that leaks will be repaired within less than 24 hours.

Financing NRW projects through public-private partnerships

One of the most important barriers to starting up a new NRW programme is often securing funding for the programme in its initial phase until the expected return on investment is realised. Many water utilities around the world are not able to overcome the initial investment, even though the business case shows a payback time of just 2-3 years. A proven solution can be to arrange a public-private partnership (PPP) between the utility and private sector companies. The PPP can be set up in different ways, e.g. between the water utility and the contractor on behalf of a group of suppliers to the programme, or by using a Performance Based Contract (PBC or ESCO) where the contractor is paid based on the savings and increased income the project has generated for the water utility. Danish companies are often open to such arrangements.

Photo credit: Ida Marie Jensen

Securing the future workforce through an innovative public-private partnership, Aarhus, Denmark
The Danish water sector has joined forces to create the Advanced Water Cycle Management Course; providing knowledge and motivation to the next generation of international water professionals. As in many countries, Danish water companies and utilities face a potential sector knowledge gap due to a retiring workforce. To pique interest in a career within the water sector and secure the future workforce, the largest research university in Denmark, Aarhus University, leading companies from the water sector and one of the largest utilities in Denmark, Aarhus Vand, joined forces in an innovative public-private partnership and educational program.

Partnership for a holistic educational program
Through a commitment to the cause by a total of nine partners and 40 guest lecturers, the international water summer school has been created. The summer school is dedicated to reducing the knowledge and workforce gap and designed to upgrade participants in advanced water cycle management skills. Through a holistic overview of water resource management, water distribution and wastewater management, participants are shown the diverse career possibilities of the water sector. Several topics are highlighted, such as groundwater mapping and modelling techniques, resource recovery from wastewater, as well as the globally important topic of non-revenue water management and water loss control.

Extended international network
The first summer school in 2019 attracted 45 participants from 13 countries. The duration of the course was 13 days and provided participants with university credits. It consisted of a combination of lectures, interactive sessions, site and company visits as well as case-based workshops. The summer school presented networking opportunities for both the participants and the water professionals. For some, the international water summer school resulted in a new career opportunity. For the companies and utilities, it indicated a promising start to securing the future workforce in partnership.

Partners involved – the collaboration
AVK, GRUNDFOS, KAMSTRUP, NIRAS, I•GIS, DHI,
Skanderborg Forsyning-AquaGlobe, Aarhus Vand,
WATEC - Aarhus University Centre for Water Technology.

Strategic water partnership to stop water losses through system integration and holistic monitoring, Denmark
Nine Danish partners formed a consortium with the objective of demonstrating the use and effect of integrated high-end solutions within water loss control based on Danish technologies and know-how. The nine partners include leading technology providers, consultants, water utilities and the Technical University of Denmark. Known as the LEAKman Project, its aim is to deliver a sole, holistic Non-Revenue Water Management system.

Demonstration of a combined leakage management approach
Initiated in 2016, the 5-year project that is financed under the auspices of the Eco-Innovation Programme that is supported by the Ministry of Environment, has an overall budget of EUR 5.7 million. The project includes several central aspects such as economic analysis of the return on investment, Economic Level of Leakage (ELL), selecting appropriate KPIs for monitoring the status and effect of different leakage management solutions as well as the implementation of interfaces between systems. The approach integrates the four key elements of leakage management: pressure management, active leakage control, pipeline management and rehabilitation, as well as speed and quality of repairs.

Two large-scale demonstration facilities have been established at the Danish water utilities Novafos and HOFOR. The implementation includes installation and use of intelligent valves, pumps, deployed noise loggers, smart meters, smart inspections, SCADA, online hydraulic modelling (Aquis), GIS and a holistic management information system (HOMIS) configured for automated calculation, display and reporting of selected key performance indicators.

Integration and connectivity is key
Many of these components are generally already in use at water utilities, however they are often installed as part of separate projects, with only little or inefficient interface between the different components. Consequently, full potential of the entire system is never reached. The LEAKman project combines several smart systems and seamlessly integrates and monitors them holistically, thereby connecting the entire water distribution network. The result is one solution that facilitates water loss reduction to less than 20 per cent for any system within just a few years – with possible reductions to below 10 per cent.

In 2020, upon completion of the demonstration facilities, the pressure is now reduced by 16 per cent in the first demonstration area, and an additional reduction of 15 per cent is planned. Consequently, a corresponding decrease in leakage level and burst frequency is expected.

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

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
INNOVATION | EXPORT | REGULATION

Ministry of Environment of Denmark

DANVA

Danish Environmental Technology Association
Association for Danish Environmental Technology Companies

DI | Water

Learn more about Danish water solutions, find more cases from around the world and connect with Danish water experts at

www.stateofgreen.com

Join us in Copenhagen for the
IWA World Water Congress & Exhibition, 11-15 September 2022

www.worldwatercongress.org

State of Green is a non-profit, public-private partnership founded by:

Confederation of Danish Industry

DANISH ENERGY

Danish Agriculture & Food Council

wind denmark

Ministry of Industry, Business and Financial Affairs

Danish Ministry of Climate, Energy and Utilities

Ministry of Environment of Denmark

Ministry of Foreign Affairs of Denmark