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REDUCING URBAN WATER LOSS

How water utilities can improve efficiency and meet future demand for water by reducing Non-Revenue Water

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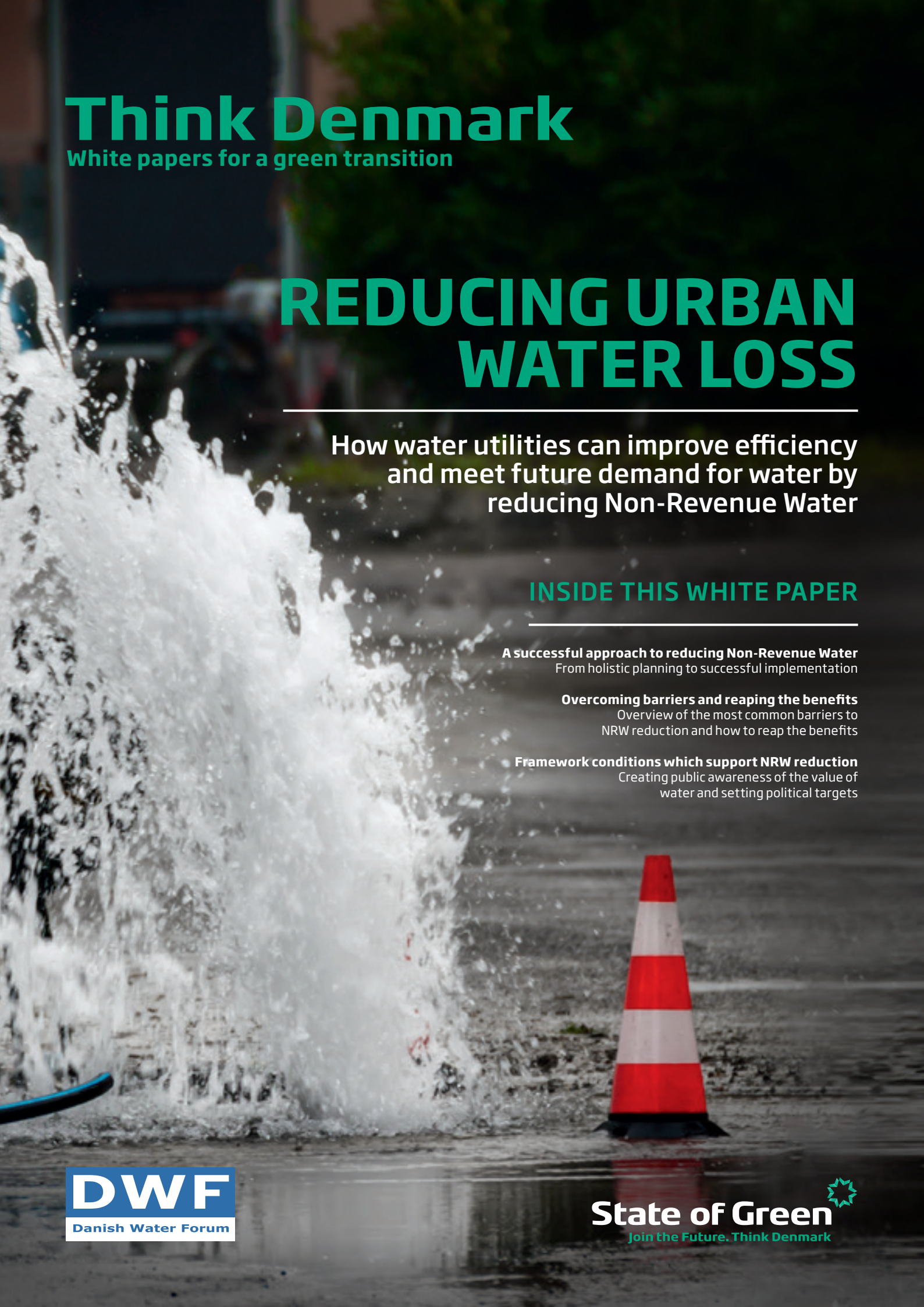

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REDUCING URBAN WATER LOSS
How water utilities can improve efficiency and meet future demand for water by reducing Non-Revenue Water
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EXECUTIVE SUMMARY

Water consumption on a global scale is estimated to increase by up to 30% by 2020 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, operation and not least reducing Non-Revenue Water is needed.

Today, 25-50% of all distributed water globally is lost or never invoiced due to illegal connections, inaccurate billing systems, inaccurate metering, leakages, deteriorating infrastructure and wrong water pressure management etc. This is all in all called 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 bring down 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 data on the water distribution that is available and the better integrated the management system is, the easier it is to get the necessary overview and subsequently prioritise investments. The first step in reducing NRW should 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 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, continuous focus must be on monitoring and optimising the water distribution to maintain a low NRW level. Ongoing monitoring and pressure management are best carried out by breaking down the distribution system into smaller and more manageable units or 'District Metering Areas'.

The quality of installed components such as valves, pumps, pipes and meters etc. also plays 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 on keeping NRW levels low.

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 costs and benefits of investing in NRW reduction will be less transparent.

Overcoming barriers to reducing NRW requires attention and involvement from several stakeholders – from politicians to local consumers – 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.

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1. THE IMPORTANCE OF REDUCING NON-REVENUE WATER

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

In many cities 25-50% of distributed water is never invoiced at the consumer. 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
'Non-Revenue Water' (NRW) is the difference between the amount of water a water utility pumps into the distribution system and the amount of water that is billed to its consumers. It comprises of:

1. **Apparent losses**, also termed 'commercial losses', which are caused by inaccurate metering, data handling errors and illegal tapping.
2. **Real losses**, also termed 'physical losses', which comprise leakage from all parts of the system and overflows at storage tanks. Real losses are caused by poor operations and maintenance and poor quality of underground assets.
3. **Unbilled authorised consumption**, which is water used for flushing, firefighting, and water provided for free to certain consumer groups.

A more detailed description is found in the 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% by 2030, 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% in less than 20 years from now. Future demand for water therefore requires a strong focus on efficient water management, operation and not least reduction of NRW.

25-50% of all distributed water is lost or never invoiced
Huge volumes of drinking water are never invoiced due to illegal connections, inaccurate billing systems, deficient consumer registration, inaccurate metering, leakages, deteriorating infrastructure, wrong water pressure management, reservoir overflow and unnecessary flushing.

In addition to simply making good business sense, reducing NRW is also of great benefit to the environment. In the long run, neglecting to reduce NRW poses a threat to the development of the entire area as 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 expansions of service, solve problems and conduct maintenance. In general, reducing the NRW by half is an achievable target for most water utilities within one to two years. A reduction at that level will generate a considerable increase in annual income from increased revenues and reduced costs.

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

- Reduced stress on the area's water resources, 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 risk of pollution related to burst and periods with low pressure or vacuum will be reduced.

IWA WATER BALANCE

System Input Volume	Authorised Consumption	Billed Authorised Consumption	Billed Metered Consumption	Revenue Water
			Billed Unmetered Consumption	
		Unbilled Authorised Consumption	Unbilled Metered Consumption	Non-Revenue Water
			Unbilled Unmetered Consumption	
	Water Losses	Apparent Losses	Unauthorised Consumption	
			Consumer Meter Inaccuracies	
		Real Losses	Leakage on Transmission and Distribution Mains	
			Leakage and Overflows at Storage Tanks	
			Leakage and Service Connections up to point of Consumer Meter	

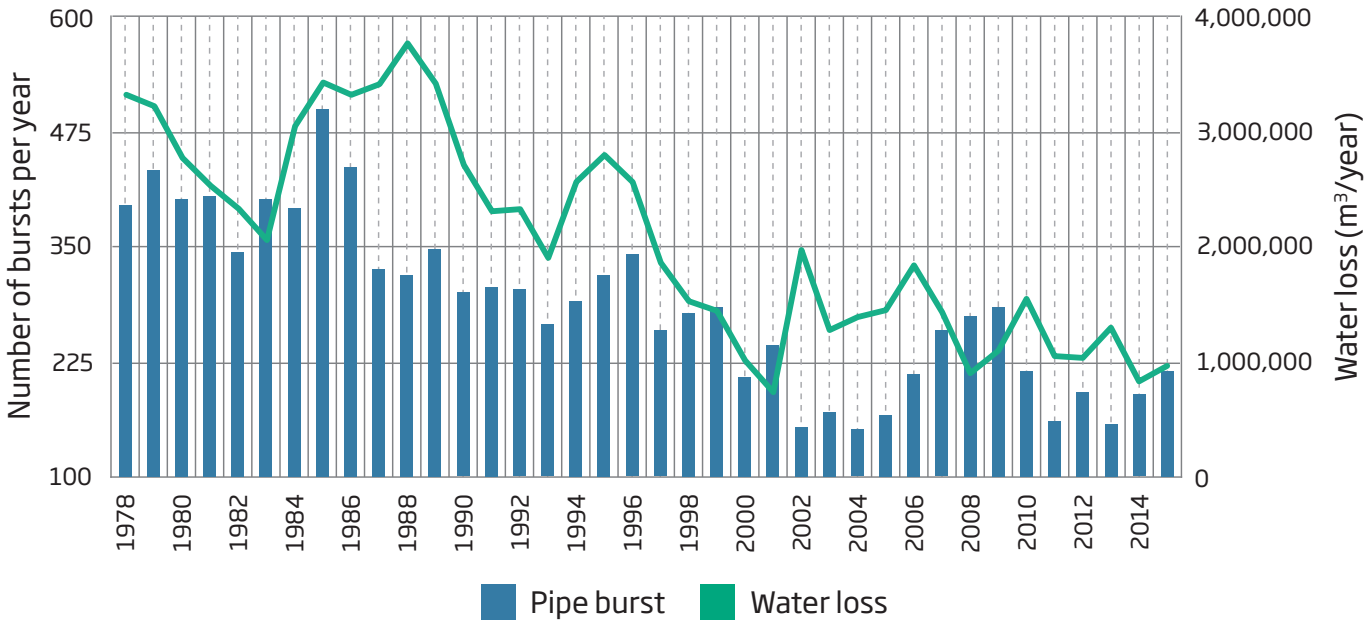
Asset Management System reduces water loss, Aarhus, Denmark

For many years NRW has been high on the agenda for Aarhus Water – the utility in Denmark's second largest city – and the NRW level has remained steady between 6.5-7.5%. The objective for Aarhus Water is to reduce the NRW level to approximately 6%. Through a determined effort since the mid-seventies, the utility has managed to reduce the number of bursts and thereby the water loss as shown in the chart. The increase in the total NRW between 2002 and 2005 followed by the reverse development in the coming 3 years was due to a test period without active leakage control in order to investigate the actual benefits of investing in this programme.

In addition to asset management, high quality construction work, leakage detection, pressure management, monitoring DMA night flows as well as an intelligent pipe replacement program, new innovative methods are planned to be developed which will benefit and improve the current work. These include a method to complement the Asset Management System to reduce leakage detection costs and the time spent on analysing data from DMAs as well as a new strategy for the design criteria on future constructions to ensure effective maintenance and leakage detection.

(Courtesy: Aarhus Water)

Pipe bursts in Aarhus 1978 - present



2. A SUCCESSFUL PROGRAMME FOR REDUCING NRW

Achieving an efficient NRW reduction through a holistic approach

Several aspects - from the initial planning phase to the day-to-day operations, the use of high quality installations and good workmanship - need to be addressed to reach low NRW levels and ensure continuous success.

A series of activities needed
Achieving and keeping the NRW-level within the Economic Leakage Level (ELL) (based on cost-benefit calculations of results of activities) requires a strong focus on planning, operation, high-quality products and skilled workmanship.

The more information and data that is available on the water distribution and the better integrated the management system is, the easier it is to get an overview and subsequently prioritise investments. A strong management system can therefore be the key to success in terms of prioritising actions and securing fast return on investments.

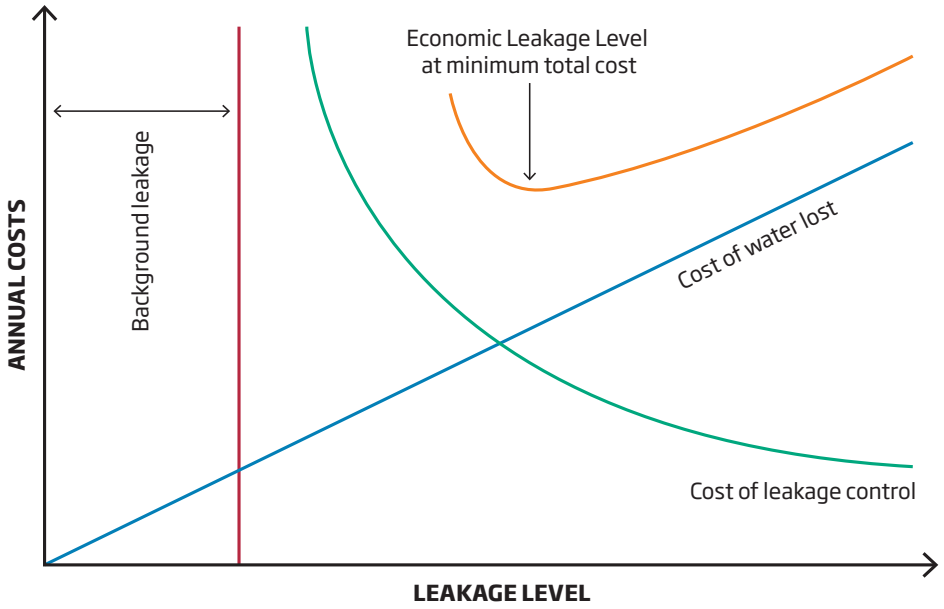
It is very important that an NRW reduction programme is established and understood from the highest level of the organisation to the lowest. NRW reduction must be an agreed strategy for the whole organisation based on a holistic NRW master plan. Capacity building at all staff levels in the utility is therefore a vital element in the start-up phase of an NRW 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 use high-quality components and products. Aspects which should be considered when purchasing and installing new components include length and scope of warranty, Total Cost of Ownership, energy consumption as well as accuracy and long-term reliability.

The different aspects of successfully reducing and maintaining a low NRW level are described more in-depth in the following chapters.

Using the right KPIs for NRW
Often NRW is shown as water not invoiced as a percentage of the amount of water pumped into the system. But many factors can affect this KPI so it is not necessarily the true picture of how the utility performs in its water distribution. The most correct figure of the NRW is cubic metres/km of pipe/day (or as a supplement to that the losses per connection litres/day). The International Water Association (IWA) also uses the term Infrastructure Leakage Index (ILI) which adjusts the measured loss, taking into account the service pressure and the length of the network.

REDUCING REAL LOSSES TO THE ECONOMIC LEAKAGE LEVEL



Achieving EU's lowest NRW level, Odense, Denmark
In the city of Odense – home town of world famous fairytale writer Hans Christian Andersen – the water utility VCS Denmark is responsible for supplying 158,000 customers with 9 million m^3 water per year. In 2015, an EU report benchmarked a number of European utilities based on their water loss (Non-Revenue Water). VCS Denmark was ranked as the best water utility with an Infrastructure Leakage Index (ILI) of merely 0.7. Real water loss in Odense stands at only 1.17 cubic meter/km/day, or 19 l/connection/day and the NRW level has been reduced to just 6%. These impressive figures are the result of a dedicated effort over the past 20 years. Back in 1992, VCS Denmark established a thorough master plan for the distribution network, changing it from a ring-connected system to a branch network. The network was restructured into zones and district metered areas (DMAs) that are relatively small; 2,150 consumers on average. All 63 DMAs are supervised by SCADA, which enables a reliable online monitoring of leakages. Leakage detection in the field is therefore only used to pinpoint leakages detected by the SCADA supervision.

(Courtesy: VCS Denmark)

3. PLANNING AND PRIORITISING NRW INITIATIVES

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

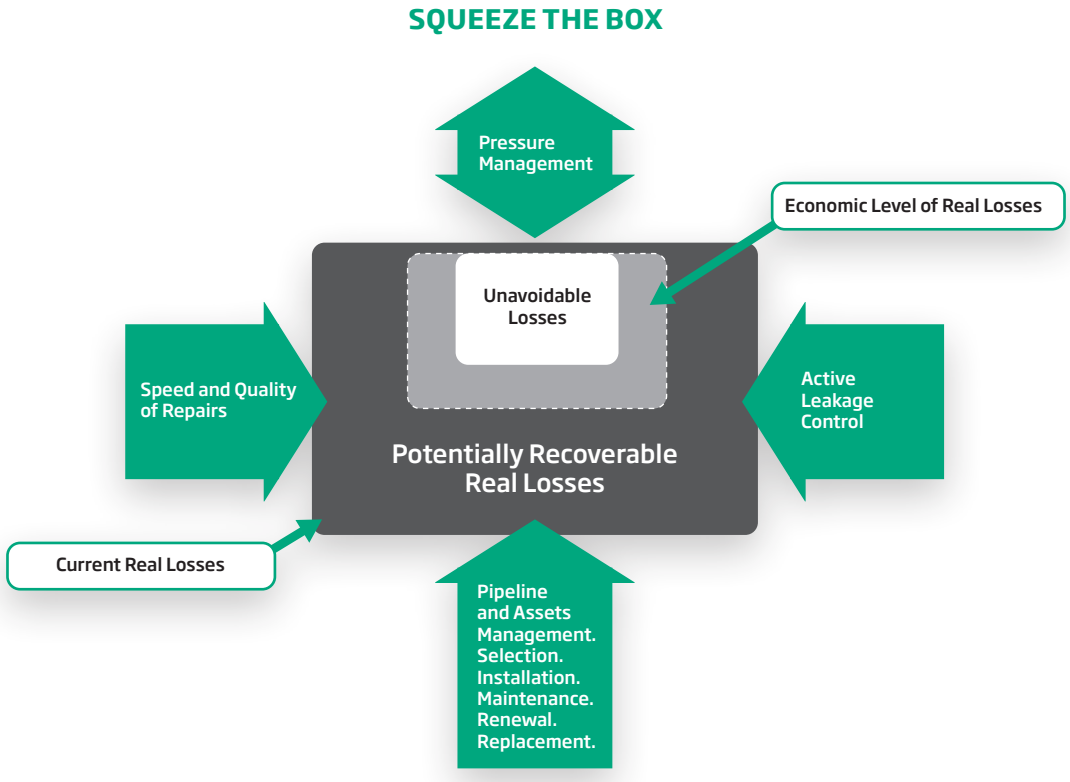
Water utilities with low quality installations and poorly maintained infrastructure and no leakage management systems may lose up to 50% of their output. To reverse this development, the first step should be to analyse the water distribution network based on available data and develop an NRW master plan for upcoming investment plans and their projected returns.

It is very important 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 whole organisation, based on a holistic NRW master plan. The master plan will analyse the water distribution network based on available data and serve as the basis for upcoming investment plans and their projected returns. Usually it is necessary to carry out a supplementary data collection to provide as complete a level of information as possible. Once completed, the master plan will provide the following information:

- A prioritised list of activities and investments in the NRW reduction programme.
- A baseline for the NRW-level and the IWA water balance.
- A breakdown of the IWA water balance, consisting of the NRW elements.
- A strategy for management systems, databases, SCADA, GIS and modelling tools.
- Calculation of Economic Level of Leakage (ELL) based on cost-benefit calculations.
- Activities developed on the basis of cost-benefit calculations (pressure management, district metering, intelligent pumping operation and leakage).
- District Metering 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. The Economic Leakage Level (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. It also takes into account the potential influence of the reduction in NRW on future investments in treatment plants, raw water extraction, 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 and assets management.

Real-time information system provides overview of city's water supply system, Cape Town, South Africa

The city of Cape Town has more than 130 reservoirs, nearly 700 pumping stations, 17,600 km of pipes and 13 water treatment plants providing 330,000 m^3 of water a day. A real-time web based information system provides all the relevant information needed to manage, operate and optimise consumption of the city's water resources. Before being implemented, Cape Town's water system was hard to control. There was plenty of data available but it was inaccessible, tucked away in different databases and differing formats. Up to 25% of the city's water supply was lost due to leakage, theft or inaccurate metering. It was a major problem for a city with limited water resources.

(Courtesy: DHI)

Delivering leakage reductions through smart use of network data, United Kingdom

Anglian Water is the largest water and water recycling company in England by territory and supplies a population of 4.5 million. Its water supply network consists of 38,000 km of pipelines, divided into 1,900 DMAs. Anglian Water is among the top performing UK water companies and is committed to reducing its water loss by more than half, from 192 Ml/day in 2015 to 94 Ml/day in 2040. Anglian Water plans to reach such an ambitious target not just by simply improving business as usual. A new approach based on the principles of innovation and transformation will drive a new focus to deliver leading standards of customer service. A key enabler to achieving its leakage target is the Integrated Leakage and Pressure Management (ILPM) system based on Schneider Electric's Water Management Suite technology. The ILPM in fact collects network data from all key corporate systems, including telemetry, GIS, billing and work management for advanced processing/calculation, information visualisation and performance monitoring.

(Courtesy: Schneider Electric and Anglian Water Services Ltd)

Reducing NRW from 45% to 10% in one year, Al Ain, Abu Dhabi

The city of Al Ain in the Emirates of Abu Dhabi (United Arab Emirates) has managed to reduce its NRW levels from as high as 45% to 10% within one year for 19 District Metering Areas (DMAs). The results were achieved through an integrated approach which included implementation of real-time hydraulic modelling, automated water balance calculations, installation of flow and pressure monitoring instruments as well as deploying noise loggers for automatic leakage detection and the Holistic Management Information System 'HOMIS' on top. HOMIS integrated all operational data systems such as GIS, SCADA, noise loggers, water quality sampling, customer care, billing and finances. By monitoring and reporting online KPIs, HOMIS helped the managers react and initiate corrective measures when specific KPIs were outside the allowed target range. In addition, a dedicated training and educational programme elevated competencies within the utility at both operational and management levels. This has enabled Al Ain in moving towards a 24/7 supply and securing safe and economic operation of the city's drinking water system.

(Courtesy: NIRAS)

Using smart water meters to reduce water loss, Jutland, Denmark

In 2011, the water utility TREFOR Vand A/S carried out an analysis of its water loss to address its high NRW issue. Afterwards, an action plan for 2012-2014 was developed using the IWA methodology. The action plan included implementation of KeyZones, pressure management, active leakage detection and optimisation of operation procedures. All mechanical meters have been replaced with smart meters and data from more than 47,000 meters is collected and processed daily. The smart meter data is included in the utility's systems to optimise its day-to-day operations. Substantial efforts and investments have been put into establishing district metering zones in the entire supply area as well as replacing old cast iron and asbestos cement pipes with PE pipes. The operation system KeyZones gathers all data relevant to water loss and provides an IWA water balance, performance indicators, GIS charts and graphs on district metering zone level. The smart meter data is particularly utilised to provide more accurate overview of daily NRW levels in the established district metering zones. In 2014, TREFOR Vand A/S successfully achieved its objective and to this day, the NRW level remains well below 10%.

(Courtesy: TREFOR Vand A/S and EnviDan)

4. KEEPING NRW LEVELS LOW THROUGHOUT THE OPERATIONAL PHASE

After implementation, continuous focus must be on monitoring and optimising the water distribution

The NRW programme has to be maintained during the operational phase. This requires daily focus on operational efforts like pressure management, leakage monitoring and rapid leakage repair. This way, it is possible to keep a low NRW-level while also achieving other benefits like energy savings and improved drinking water quality.

NRW Management
The NRW management concept is based on the principle of breaking the distribution system down into smaller and more manageable units – so-called District Metering Areas (DMAs). First, a hydraulic model is used to calculate the optimal design of DMAs. Afterwards, the system can be further developed by establishing online leakage monitoring and pressure management in each of the established DMAs and designing Pressure Management Areas (PMA) based on hydraulic modelling. As the demand for water varies widely throughout the day, controlling the pumps in each specific DMA according to the pattern of usage allows the water pressure to be adjusted to demand which reduces the risk of pipe bursts. Pressure management can also reduce energy consumption for pumping by allowing for a lower pressure during off-peak hours.

Integrating NRW into day-to-day operations
Controlling NRW is a long-term and ongoing project. Focus during the operational phase should continuously be on:

- Analysis of the NRW level based on the water balance in each DMA.
- Optimisation of the DMA performance based on ELL for each DMA.
- Installation of smart meters to secure continuous reliable data from the distribution system.
- Implementation of active leakage detection in hot spot areas based on NRW-smart analyses and use of acoustic noise loggers.
- Emergency leakage repairs based on an online alarm system.
- Training and capacity building to improve skills of employees.
- Pipe replacement based on a rehabilitation plan targeted at prioritised areas.

Ongoing rehabilitation programme
In addition to the daily NRW management, successful NRW reduction requires a long-term rehabilitation strategy for the network. Water distribution networks are often constructed over a period of many years and continuously adjusted to urban development and new regulatory requirements for drinking water supply. Pipe materials, valves and other components as well as construction methods have also changed over time and the potentials in upgrading to best available technologies are often quite significant.

Danish water utilities have implemented a number of IT tools for strategic rehabilitation planning of transmission and distribution network. A rehabilitation plan should support water utilities with the following:

- Long-term investment plan and updates on budgets.
- Continuous overview of rehabilitation project.
- Prioritisation of rehabilitation activities.
- Intelligent use of data.
- Documentation of rehabilitation strategy.

Leakage monitoring and control
Modern Information Communication Technology tools can be used to design, monitor and report Key Performance Indicators (KPIs) for NRW. Based on this, water utilities can establish a long-term rolling plan for their NRW operations which can support the operational management in carrying out pressure management and active leakage control in the network.

Using online water meters at consumer level means that the operator can follow the water balance for each DMA very precisely. The first Danish water utilities to have implemented online meters at consumer level see huge benefits in terms of faster reaction times on leakage repairs.

Using permanently deployed acoustic noise loggers with automated data collection allows pipe burst to be registered, reported and localised within 24 hours.

Together with the traditional Minimum Night Flow and estimated leakage, these technologies provide a proper set of KPIs which focus directly on leakage.

Demand Driven Distribution, Cremona, Italy
The water utility Padania Acque Gestione in Northern Italy was presented with a problem by one of the towns connected to its water supply system. Parts of the town's pipe network consisted of a smaller cross-section which meant that it was not possible to reduce the pressure in the pipes in proportion to the flow supplied. A solution was found using the Grundfos Demand Driven Distribution controller. By using pressure transducers at the ends of the water distribution network, pressure values are measured and sent to the Demand Driven Distribution controller. The controller ensures optimum pressure which reduces water hammer and thereby water loss. The starting pressure was reduced from 6.0 bar, to the current average values of about 4.2 bar, with peaks up to 5.3 bar. The pressure recorded on the terminal by the remote pressure sensor unit has remained steady at around 3.0 bar. The estimated annual savings are projected to be approximately 47,000 kWh, which equates to a savings of about EUR 7,500/year - or 17% per year. Leakage reduction was 25,000 m^3/year or approximately 30%.

(Courtesy: Grundfos and Padania Acque Gestione S.P.A)

Quick detection of leaks with district metering, Langeland, Denmark
Due to the geographical layout of its distribution area, Langeland Water Supply only used to read its consumers' water meters once a year, making leaks next to impossible to detect. However, after having installed ultrasonic water meters and a mobile reading solution from Kamstrup, the water utility now gets a regular delivery of rich data about the consumption and its supply network. To enhance its leakage detection, Langeland Water Supply chose to set up DMAs - a decision which quickly paid off. For two Mondays in a row during the summer of 2015, the water utility first read one of the district meters and then all the water meters in that area. A comparison of the readings revealed that approx. 350 m^3 of water had been lost in that week. According to the water utility's operations manager, this method proved both time-saving and cost-efficient as detecting such a leak would previously have required a significant amount of man hours and taken up to several months.

(Courtesy: Kamstrup A/S & Langeland Water Supply)

Faster reaction time on unavoidable leakages pays off, Roskilde, Denmark

Avoiding leakages on water pipes altogether is not possible as even new pipes can experience breaks. Therefore, implementing a strategy of proactive leakage detection through permanent surveillance and identification of pipelines in problem areas can save water utilities both time and maintenance costs. The Danish water utility Fors A/S monitors its pipes 24/7 by using noise loggers which are placed on the pipelines and react to noise from leakages. When the loggers detect a possible leakage in a specific area, an alarm is automatically sent to the utility's technicians through the online monitoring software ALMOS LEAK. The detailed location of the leakage still needs to be conducted on site but the system allows the utility to act on the alarm right away and saves many work hours compared to the work method used before the permanent monitoring equipment was installed. As a result, Fors A/S has managed to reduce its NRW significantly to below 10% in its monitored areas. Furthermore, unnecessary nuisance for the utility's consumers is avoided as Fors A/S is able to plan and carry out repairs at times where there is a low flow in the system, resulting in a more stable water supply.

(Courtesy: Leif Koch and Fors A/S)

AGE OF PIPELINES IN COPENHAGEN:

Keeping NRW low through good management, Copenhagen, Denmark

The Greater Copenhagen Utility (HOFOR) supplies approximately 700,000 consumers in Copenhagen with water. The residents of the Danish capital consume a total of approx. 31 million m^3 water annually. The distribution network in Copenhagen has a very high average age with 21% of the network pipes being more 100 years old. Despite this, the utility managed to keep the NRW level at just 8% in 2015. The real pipe loss in Copenhagen that year was 6.3 m^3/km/day and the Infrastructure Leakage Index (ILI) was 2.5. A low NRW value is achieved through good planning and maintenance. The real water loss has been kept low through continuous leakage detection and good rehabilitation planning. The network rehabilitation is based on a systematic selection of pipes which are prone to burst, a selection which is based on the pipe material, pipe age and the burst history. In the future HOFOR is looking to improve the planning of network rehabilitation by introducing asset management.

(Courtesy: HOFOR A/S)

5. HIGH-QUALITY EQUIPMENT AND WORKMANSHIP

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

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

It is apparent that the quality of installed components or equipment (pipes, valves, pumps and meters etc.) plays a key factor in reducing real water losses. An important argument for choosing high quality products is the Total Cost of Ownership. Since replacements and repairs are often far more expensive than the product itself, the expected operating costs and lifespan of installed products should be included in the selection criteria of the tendering process.

Avoiding physical losses by minimising leakages in pipes or valves
Water loss adds significantly to operating costs. Leakages can be caused by 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 therefore important that all equipment and installations are made from quality materials to ensure they will function properly for many years. Only quality products with a long warranty should be used and all equipment should be selected based on the principals of 'Lifetime Cost' or 'Total Cost of Ownership' and not simply on the initial purchasing price.

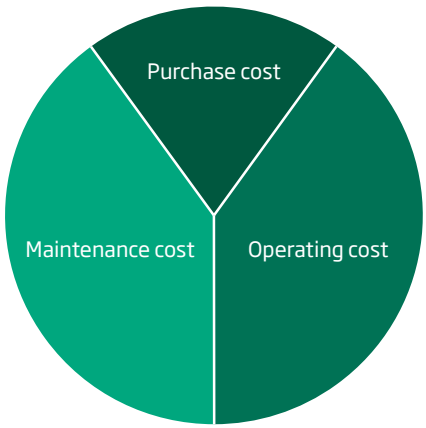
High-quality materials ensures long lifetime
PE pipelines with estimated durability of 80-100 years are used for nearly all water distribution networks and service pipes in Denmark and welding and other joints of the PE-pipes must be carried out by well-educated staff to ensure a correspondingly long lifetime of the networks. By choosing high-quality shut-off valves, leakages from the valve itself can be avoided. Gate valves with high-quality gasket of rubber ensure that the valves are 100% 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 takes a committed management and trained staff that continuously work on keeping NRW levels low. A comprehensive re-evaluation of the water utility's priorities as well as support and full understanding of the importance of NRW reduction from the management level and all the way down in the organisation is needed.

The management level must understand and prioritise the activities of the NRW programme and the benefits of purchasing equipment with high accuracy, reliability and low Total Cost of Ownership as purchasing the cheapest offer might not be the best or most cost-efficient solution to reducing NRW in the long term. In order for the water utility to adapt and reap the full benefits from an NRW management system, a comprehensive training and technology transfer programme must be implemented to secure continuous good results.

Training of technical staff
The technical staff has to receive training in how to use new tools like GIS, hydraulic models, leakage monitoring systems, noise loggers and smart meters. The training programme should include staff at all levels and be tailored to the specific needs of the different work functions, from the planners to the craftsmen who all need to understand the necessity of following the specific procedures and QA systems. External partners also have to be taken into account and instructed in how to follow the water utility's guidelines and QA system to make sure a high quality level of their work.

TOTAL COST OF OWNERSHIP



The distribution of purchasing, operating and maintenance costs will vary depending on product type (e.g. pipes, valves, pumps or water meters). However, all three aspects must be taken into consideration when purchasing new equipment.

Reducing water loss with accurate metering, Gotland, Sweden

On Sweden's largest island, Gotland, hard water created by the island's calcareous rocks caused deposits in the region's 12,000 mechanical water meters. The build-up of lime scale, calcium, iron and sand lowered the accuracy of the mechanical meters and caused them to display incorrect water usage – or in some cases – stop working altogether. This forced the region's water department to replace some of the meters after only three years of use as opposed to the usual ten years. A decision was therefore made to invest in more expensive, but longer lasting, ultrasonic water meters from Kamstrup. The ultrasonic water meters are resistant to mineral deposits as they do not have any moving parts, ensuring unrivalled accuracy and lowering the unbilled consumption throughout their 16-year lifetime. Moreover, the built-in leakage detection in the meters alerts Region Gotland's water department and pinpoints the location of leaks across their network, ensuring that leaks are quickly fixed and water loss is reduced.

(Courtesy: Kamstrup A/S & Region Gotland)

Valve replacement reduces water loss, Romania

A large water supply utility in Romania, covering a water network of about 400 km and a population of approximately 200,000 people, decided to replace its old pipes with new PE pipes using AVK gate valves as well as new and modern solutions for pumping and pressure regulation. The modernisation and extension of the water and wastewater network reduced the utility's water loss by more than 10% and resulted in big savings on operational costs. The problem with the previously used metal seated gate valves was that they were mounted in concrete wells and often caused problems in relation to shut-off tightness. In contrast, the newly installed AVK resilient seated gate valves have been mounted directly underground and feature rubber which absorbs impurities and are thus able to shut tightly for a lifetime. The Romanian water supply utility also installed AVK air valves which furthermore had a positive impact on the utility's network as it led to both a reduction in hydraulic problems and a decrease in energy consumption needed for pumping.

(Courtesy: AVK)

6. BARRIERS TO SUCCESSFUL NRW REDUCTION

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

NRW is a well-understood challenge by most water utilities but only 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.

Common barriers to NRW reduction
Reducing NRW should have highest priority for every water utility, however it seems like nothing is really happening in many water utilities despite high NRW levels. Some of the most common reasons for this situation and lack of action might be:

- **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.
- **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 consumers tampering with their water meters.
- **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.
- **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 lifetime of the products. This will often result in poorer solutions and increase the need for replacement afterwards.
- **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.
- **Fear of negative image:** In areas which are suffering from droughts where the water utility has asked consumers to reduce their own water consumption, it may be viewed as problematic to admit to excessive leakage problems.
- **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 resiliency goals.

Reaping the benefits of reducing NRW
There are many benefits to be reaped from adopting and successfully implementing a Non-Revenue Water reduction programme. Reducing urban water loss can postpone the need for additional water resources in cities with a growing population as up to 30% more people can potentially be served simply 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 Economic Leakage Level.

Considerable energy savings
If 25-50% of the water produced is lost through leakages and never reaches the end consumers, it also means that the energy used to treat and distribute the water is wasted. It is possible to obtain 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 (commercial loss) caused by inaccurate metering and data handling errors etc. typically makes up 25-75% 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 consumers. This will be described further in the next chapter.

Reducing NRW despite historically little focus on the issue, Oslo, Norway

Historically, Norway has had almost unlimited access to drinking water at quite low costs. As a result, there has only been little focus on NRW and NRW-levels around 50% were not unusual. Over the past 5-10 years, though, this has changed as high NRW also leads to high maintenance and production costs as well as overcapacity. In Oslo, several initiatives are being implemented between 2015-2020 to reduce NRW-levels to 20% as an initial goal. An online hydraulic modelling system 'Aquis' by Schneider Electric has been implemented and integrated with the SCADA system, ensuring a continuous real-time overview of the state of the distribution system. The model is used for both online monitoring as well as planning, design and optimisation activities. Focus has been on optimisation of the existing system to minimise background leakage and to prioritise the ongoing leakage activities. An important aspect has been to utilise the hydraulic model to check and verify the existing DMA-boundaries and identify optimal points for further instrumentation to ensure efficient monitoring of NRW-levels and support for leakage detection and reduction activities.

(Courtesy: NIRAS)

7. THE IMPORTANCE OF PUBLIC AWARENESS AND POLITICAL TARGETS

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

It requires special attention and improved service to convince consumers that water has a value and that the water bill is a sign of priceless and essential benefits. Consumers must be taught to appreciate the value of having a stable supply of safe drinking water. This requires both political attention and priority.

The value of water and respect for the water bill
Awareness and understanding of the value of water is very weak in many countries and often the price for 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 a stable supply of clean and safe tap water. The subsidisation of the water price must be phased out and the price for water must 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. NGO's 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 development of a sustainable water supply.

Economic growth can go hand-in-hand with reduced water consumption
The notion that economic growth and increasing resource consumption go hand-in-hand is incorrect. As Denmark has demonstrated, introducing measures to reduce water consumption is not a threat to economic development. The Danish water consumption has decreased by nearly 40% since 1980 while the country's GDP has increased by 75% during that same period. In addition, the national average for non-revenue water has been reduced to 8% due to political focus on the problem and legal regulation which has motivated the water utilities and technology providers to develop new cost-efficient leakage monitoring technologies and leakage management systems.

Economic incentives to reduce NRW
Economic incentives are important drivers for changes in behaviour. 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 twenty years, regulation has required certified metering of all water consumption at consumer level in Denmark. Futhermore, Danish authorities impose high penalties on water utilities that do not reduce their NRW level to less than 10% through taxes which apply to both water consumed and 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 others. Each year, the Danish Water and Wastewater Association (DANVA) collects and publishes performance data – including NRW data – from more than 130 Danish water and wastewater 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 CO_2-reduction is receiving growing political attention around the world. 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 especially the change in pressure and closing of leaks can lead to considerable energy savings.

8. SECURING FUTURE DEVELOPMENTS IN NRW REDUCTION

Innovation and new partnerships as drivers for continuous development

State-of-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 the ELL and improving the efficiency of water distribution.

In Denmark, great emphasis is put on research and innovation programmes to ensure continuous improvements in NRW projects. Companies, 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 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 can therefore boost innovation in the 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 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 is run by the Ministry of Environment and Food.

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 consumers. As a result, they are generally very open to cooperating with other stakeholders in the water sector in developing new and improving existing practices and technologies. This could for instance include advanced use of software and communication technology combined with smart meters to collect important information about the consumption in order to optimise their water supply to the network and save energy.

One example of this type of technological development is Danish water utilities which are implementing smart water meters and noise logging tools instead of traditional mechanical meters in order to collect more reliable data from the distribution system and thereby manage their NRW even better. The data from the smart meters, collected both at the consumers and in strategic locations in the distribution system, provide water utilities with more accurate daily NRW levels in each DMA which enables them to optimise their NRW activities on a daily basis. The use of automated data collection instead of using traditional leakage detection equipment makes it possible to register, report and localise bursts within less than 24 hours.

Creating a win-win situation
Strategic partnerships should be based on a win-win situation for all partners involved. While the water utilities are able to test and influence the development of new technologies, the technology providers are able to test their products onsite at their customers which enables them to make valuable adjustments before final product launch. Most NRW partnerships in Denmark focus on improving functionality, lowering energy consumption and reducing Total Cost of Ownership.

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 are not able to overcome the initial investment, even though the business case shows a payback time of just 2-3 years. A well-documented 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.

Unique Danish partnership against global water losses
Nine Danish partners have formed a consortium with the objective to demonstrate the use and effect of integrated high-end solutions within Leakage Management based on Danish technologies and know-how. The nine partners represent leading technology providers, consultants, water utilities and the Technical University of Denmark.

The project – named the LEAKman project – is initiated to demonstrate Danish solutions for reducing urban water loss and pave the way for new technological developments.

It includes several vital aspects such as economic analysis of the return on investment, Economic Leakage Level (ELL), selecting appropriate KPIs for monitoring the status and effect of different leakage management solutions as well as the implementation of interfaces between the systems.

Two large-scale demonstration facilities have been initiated at the Danish water utilities Nordvand and HOFOR (Greater Copenhagen Utility). The demonstration facilities are using state-of-the-art tools and techniques in order to test, verify and optimise leakage management solutions which will reduce and maintain NRW at a level of 4-6%. 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.

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. Many of these components are 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. As a consequence, the full potential of the entire system is never reached.

A key point of the implementation is to establish seamless and generic interfaces between all components in order to optimise the value of each individual system when combined with the other systems.

The LEAKman project is a 4-year project under the Eco-Innovation Programme supported by the Ministry of Environment and Food which runs from 2016 to 2019 and has an overall budget of EUR 5.7 million.

(Courtesy: NIRAS, Grundfos, Schneider Electric, AVK, Kamstrup, Leif Koch, Technical University of Denmark, HOFOR and Nordvand)

Reducing Non-Revenue Water in Chijin Island, Taiwan

Chijin Island in Taiwan has experienced significant historical problems with physical water loss which have caused disruptions to the island's water supply and resulted in an NRW level as high as 45%. To reverse this, Taiwan Water Company engaged in an NRW reduction project together with Rambøll, Leif Koch and DHI in 2014. As part of the project, the many components involved in determining the IWA water balance as part of the NRW investigation were presented, discussed and calculated with the Taiwan Water Company. From a management point of view, it was decided to start with leakage detection to get an upfront significant reduction of NRW and then as the next step to setup an overall NRW master plan based on an online solution. Leakage operators from Taiwan Water Company were trained in how to implement active leakage detection as an effective tool to minimise leakages. In one week of training, the leakage detection specialists from Leif Koch detected 13 major leakages together with the local staff which provided a significant reduction in NRW. The project illustrated that together with the overall NRW master plan, ongoing leakage detection and repairs on the pipeline system could reduce the NRW. The KPIs were determined to reduce NRW by 10% within the next 5 years.

(Courtesy: Rambøll, Leif Koch, DHI and the Danish Ministry of Foreign Affairs)

Reducing urban water loss in Chittagong, Bangladesh

As the local water utility for Chittagong water network, CWASA is required to deliver an equitable water supply for the entire population in its area. However, it was estimated that the water loss was approximately 60%. In order to reduce its water loss, a number of critical elements needed to be addressed, including rationalisation, improvement of operation and expansion of the network. This required implementation of DMAs, pressure management and flow control, construction of new pipes as well as active leakage control. In the initial phase of the project, up-to-date information of the network was gathered with the help of GIS and hydraulic modelling. In addition, assessment of initial losses – both commercial and real – as well as identification and prioritisation of problem areas were carried out, resulting in identification of 137 km of pipelines to be replaced. Following the completion of the pipe rehabilitation and construction phase, the next steps will be to implement the DMAs and active leakage control as well as operational tools to secure continuous management of the network and a stable water supply.

(Courtesy: SWECO)

9. DENMARK KNOWS WATER

If your goal is smart and efficient water solutions, Denmark is ready as your partner

Water is an increasingly scarce resource in most parts of the world and we need to rethink how we use it. Denmark holds a long tradition of integrated water management and is committed to take responsibility and contribute to solving the major global water challenges.

A long tradition of sustainable water management
As awareness about sustainable water practices has increased, Denmark has spent the past decades building expertise within water efficiency and water management. Today, our tap water is as pure as the finest spring water, water loss in our pipelines has been reduced to less than 8%, wastewater is treated efficiently with a strong focus on energy and resource recovery and the water in our capital's harbour is clean enough to swim in.

The knowledge we have about water resources, security and efficiency is no coincidence. Successive governments have addressed our country's limited natural resources and the Danish water sector holds a long tradition of water utilities, technology providers, consulting companies and universities working jointly together to promote integrated solutions for efficient and sustainable water management.

A shared water vision for the future
The close collaboration between multiple stakeholders has put Denmark at the forefront of research, technology development, know-how and best-practice in integrated water management, urban drainage, water supply, wastewater treatment as well as governance and ensuring public awareness and support for water policies.

Denmark is prepared to take responsibility in solving the world's major water challenges and has ambitious plans for its water sector. A water vision for 2025 has been created through dialogue between the Danish water sector and the Ministry of Environment and Food with the intention of developing Denmark's position as a water hub for intelligent and efficient water solutions. The aim is to create solutions which will increase access to clean water and sanitation, promote efficient use of water resources, improve the competitiveness of water consuming industries, lead to a cleaner global environment and protect cities from floods and storm surges.

As a country, we see great opportunity for mutual benefit in the transfer of knowledge and we aim at turning global water challenges into opportunities for sustainable growth.

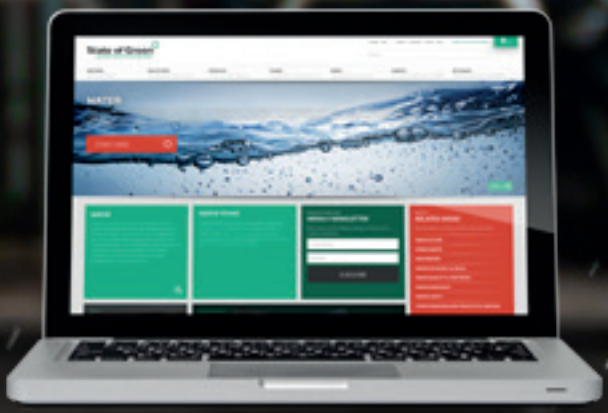
Explore water solutions online or experience them live in Denmark
We invite you to explore the newest Danish water solutions, policies and news online at www.stateofgreen.com/water. You can also visit Denmark on a State of Green Water Tour where you can experience innovative water solutions first-hand and take advantage of the lessons learned by leading Danish companies and utilities.

For more information about State of Green Water Tours, please visit:
www.stateofgren.com/tours

"Danish water companies, utilities and organisations have shown that by working together, it is possible to create more innovative solutions which lead to added value for both their customers and society as a whole. This is a great example of how Denmark contributes to finding solutions to the major water challenges the world faces."
Esben Lunde Larsen, Minister for the Environment and Food, Denmark

the international water association

Join us in Copenhagen for the IWA World Water Congress & Exhibition in 2020
Denmark is proud to host the IWA World Water Congress & Exhibition on 18-23 October 2020. Proposed congress topics are "Water for smart liveable cities", "Water - Energy - Food Nexus" and "Recruitment and career development in the water sector". The proposed topics address future water challenges all over the world. Before, during and after the conference, a united Danish water sector looks forward to demonstrating smart water technology, system solutions and discussing governance and policy in order to secure resilience in the future in towns, basins and cities around the world.
Read more at www.iwa2020copenhagen.dk



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

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Ministry of Environment and Food of Denmark