Water UK

A Leakage Routemap to 2050

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A Leakage
Routemap To 2050

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Glossary

ALC

Active leakage control, the process of finding leaks in a proactive manner.

DMA

District Meter Area, a discrete area of network that through permanent measurement of flow using operational metering on the networks. The areas are used to estimate leakage, combining flows at night with estimates of customer consumption. This is done via measuring flow into and out of an area typically containing 500-2000 properties.

AMP

Asset Management Period, the five-year periods used in the regulatory cycle between price reviews. AMP7 runs from April 2020 – March 2025, AMP8 runs from April 2025 – March 2030.

PR19

The Price Review completed in 2019 that set the prices that the water companies can charge their customers, from April 2020 – March 2025 (AMP7).

WRMP

Water Resources Management Plan, the regulatory document sent to the Environmental Agency that sets out the water resources position of a company or region of the company.

PIC

Public Interest Commitment, a set of the commitments made by Water UK on behalf of the English water companies to improve service to customers and protect the environment.

ODI

Outcome Delivery Incentive, the mechanism in PR19 that water companies are rewarded for achieving commitments and penalised for failing to deliver.

NIC

National Infrastructure Commission, the commission carries out impartial in-depth studies into the UK's major infrastructure needs and makes recommendations to the government.

SELL

Sustainable economic level of leakage, the level of leakage for each company when the cost to produce water (with all the social and environmental impacts) is less expensive than finding the equivalent volume of water through leakage reduction activities.

PODDS

Prediction of Discolouration in Distribution Systems, a Sheffield University led project into how water quality can be improved for customers through pipe network design and operations.

FOREWORD

Water Uk

Christine McGourty, Chief Executive

In 2019, the water companies of England set themselves a goal of tripling the pace of leakage reduction – achieving this decade (2020-2030) the same level of improvement that had previously taken thirty years (1990-2020).

This accelerated effort will save almost a billion litres of water per day by 2030 – around a third of current losses - putting us on track ultimately to halve leakage by 2050.

With some of our 347,000 km of pipes dating back to the 19th century, this will be an enormous challenge. It will mean every water company doing things differently, and a swathe of further innovation in how we prevent, find, and treat leaks – something laid out in further detail in the annex to this report.

Although difficult, this work is vital. Reductions in leakage contribute about a third of the new water we will need by mid-century to protect against drought. They are also essential for achieving our goal of leaving more water in nature – every litre saved in leakage allows us to reduce abstraction from rivers and groundwater. That is why we have created this Routemap, which provides the whole sector with a framework for action as companies build their next Water Resource Management Plans for the coming decades.

This document has been a huge undertaking. To create it we held dozens of workshops and other conversations, and:

- talked to those cities and countries around the world that have achieved the strongest levels of performance
- looked carefully at best practice in this country, evaluating the specific challenges present in different geographies and the breakthroughs achieved by different companies
- modelled different routes for achieving progress over coming decades, with their associated costs and benefits
- constructed future scenarios to deal with possible uncertainty, and
- formed conclusions on the biggest challenges, priorities and possible approaches

Through that work, it is clear that progress will depend on four things:

1. even more effort from industry and its supply chain, with focus and ambition matched by ever-more sharing of experience, investment in innovation, and collaboration on evidence and best practice to allow each company to deal with its unique challenges
2. a step-change in the replacement rates of old pipes to tackle 'background leakage' (which will otherwise represent an increasing proportion of losses) as we run out of more traditional approaches like Active Leakage Control
3. support from regulators and Government for the biggest priorities on innovation, investment, the interactions between targets, and on the best approach to dealing with customer-owned pipes as traditional regulatory approaches may not be adequate for securing the progress we need
4. greater collaboration with local authorities and highways agencies, given the degree of underground work that will be needed this decade on pipes

As an industry, we have made a number of commitments about what each company will do to strengthen progress and identified an 'adaptive pathway' approach for ensuring momentum regardless of which of four future scenarios ultimately comes to pass. We have also tried to demonstrate how decisions by regulators and government could support the achievement of progress.

Leakage rates may be as low as they've ever been, but we are still losing the equivalent of 1,245 Olympic swimming pools per day. Maintaining recent progress will be possible only with determination, collaboration, and support from the supply chain, government and regulators. That is how we will build a water network fit for the next century and beyond.

Christine McGourty, CEO

1.1 The Public Interest Commitment

Water is a precious resource. Water resources management is a key activity of the water companies. The management of leakage has been a key part of the strategy to ensure there is sufficient water for everyone's needs for decades.

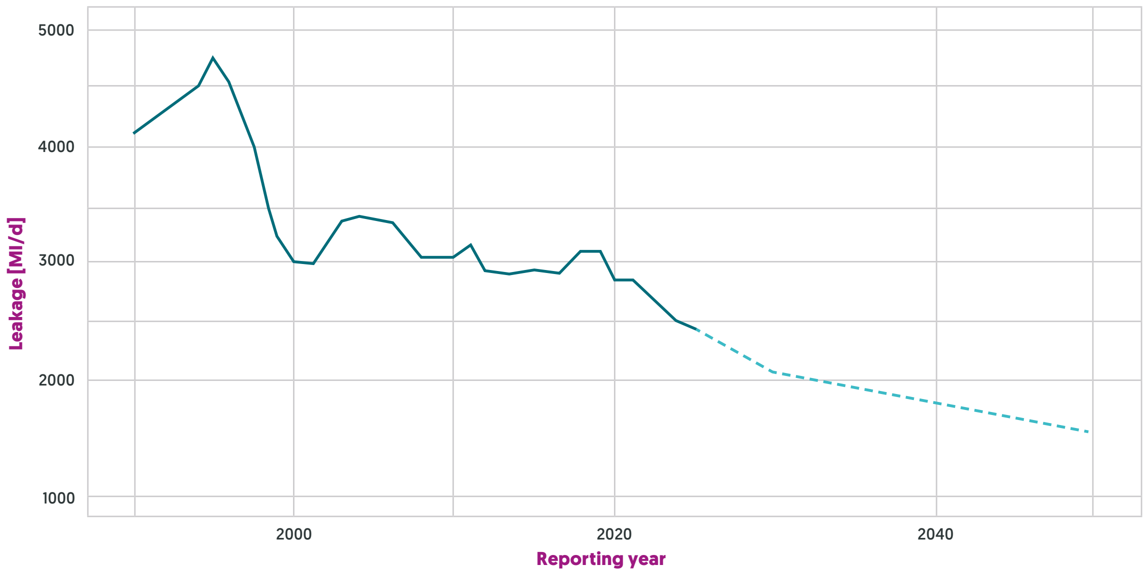
The water sector in England and Wales has been managing leakage levels against specific targets since 1997. This followed a severe drought starting in 1995, which left reservoir levels very low. Mandatory leakage targets were introduced following an emergency leakage summit in May 1997; and leakage targets of one form or another have been in place since. Leading up to this were a series of pioneering research projects and reports, starting with the "National Water Council Standing Technical Committee Report No. 26"[1] on leakage control published in 1980. Following this a series of reports were published by the water sector which came to be known as the "Managing Leakage" series of reports published in 1994[2].

These reports set the benchmark for leakage best practice around the world. Many of the current practices for controlling leakage around the world have their origins in these reports.

In 2019 the English water companies made a Public Interest Commitment (PIC)[3][4] to "Triple the rate of sector-wide leakage reduction" by 2030. The water sector has also taken up the National Infrastructure Commission's (NIC)[5] challenge by committing to halving leakage from 2018 levels by 2050. For context the historical performance of the English water companies and the PIC and NIC challenge are presented in Figure 1.1.

[1] Technical Working Group on Waste of Water. Leakage Control Policy and Practice. National Water Council Standing Technical Committee Report No. 26, July 1980.
[2] UK Water Industry. Managing Leakage series of reports, October 1994.
[3] Water UK. Public Interest Commitment, April 2019. https://www.water.org.uk/publication/public-interest-commitment/
[4] Water UK. Public Interest Commitment Update, October 2019. https://www.water.org.uk/wp-content/uploads/2019/10/Water-UK-Public-Interest-Commitment-update-October-2019-1.pdf
[5] National Infrastructure Commission. Preparing for a drier future -England's water infrastructure needs, April 2018. https://nic.org.uk/app/uploads/NIC-Preparing-for-a-Drier-Future-26-April-2018.pdf

Figure 1.1 – Leakage performance and commitments in England from privatisation to 2050



Why is leakage important?

Even after the large reduction in leakage since the mid 1990's, leakage currently ranges from about 80 to 170 l/property/day, this is about the equivalent of having one extra person in every home in the UK. The level of leakage varies considerably due to a complex range of factors. These factors can be related to the infrastructure assets that can vary in terms of condition and performance, and this may be related to age, material, how pipes were laid, soil and environmental considerations, water quality, water pressure, external pressure from ground movement, depth, third party damage and weather/climate. Water is essential for life, and with a changing climate and increased risk that droughts will become more frequent it is important to ensure that a continuous supply of safe, clean drinking water is available. The National Framework for Water Resources[6] sets out that public water supply needs that factor in population growth, can be met through a combination of reducing consumption, reducing leakage, increasing supplies and moving water from areas of surplus to areas of need.

Reducing leakage alone will not be sufficient to meet the longer-term requirements, however the reduction in leakage is a key part of the overall solution Therefore, leakage is important for several reasons:

- It is a waste of a precious resource by taking water out of the environment. Even if leakage returns water to the environment, it is often lower down in the catchment and can impact water resources.
- Water lost from the system through leakage reduces the ability to ensure public water supplies are resilient to drought, with associated implications in terms of costs and the environment.
- In areas where the supply of water is limited, alternate sources are needed.
- It is a waste of carbon; every drop of water leaking from the network has been treated to drinking water standards and pumped. This also wastes chemicals used in the treatment processes.
- It poses a potential risk to buildings and transport infrastructure.
- Customers do not like leakage because it is seen as inefficient, and a barrier to asking customers to conserve water.
- Reducing leakage can also be interlinked with other benefits. For example the removal of lead supply pipes can improve water quality at customer taps as well as providing leakage benefits.

Leakage represents a national problem, and water companies are working together to produce regional plans, along with considering strategic options to transfer water from regions of surplus to regions that face deficits. It is therefore important to recognise that there are national benefits to reducing leakage, irrespective of the local supply-demand conditions

[6] Environment Agency, Meeting our future water needs: a national framework for water resources, March 2020.

1.2 What is leakage?

Leakage is the escape of water from pipes or fittings, and service reservoirs, and in the context of regulatory reporting is referred to as "total leakage". This represents the loss of water from water networks and service reservoirs downstream from the point of treatment. In the longer-term, the loss of water from the point of abstraction rather than the point at which water is input into the supply system may need to be considered. However, for the purposes of this report leakage refers to total leakage as per the current reporting methodology.

The key factors that influence how much water escapes from the network each day are how many leaks there are in the network, the physical size of each point of leakage and the pressure of water inside the pipe. Total leakage is also impacted by the number of days a leak is allowed to run.

Clearly a network with no holes or points of leakage will have zero leakage, but water networks leak for a variety of reasons:

- Corrosion or deterioration of pipes, fittings or seals. This can be accelerated in aggressive soil conditions as an external factor, or internally due to corrosive water quality.
- Poor installation quality or practices, leading to weak joints or other points of weakness.
- Thermal expansion and contraction of pipes, leading to opening of joints or cracks in the pipes.
- Water networks are pressurised, higher pressures and pressure surges can contribute to leakage over time.
- Ground movement and stresses placed on underground pipes due to weather or climatic factors, or due to traffic loading.
- 3rd party damage.
- Structural failure of pipes and fittings. Often due to a combination of the above factors.

Some water pipes have been in the ground for more than 150 years and leaks can break out on pipes from the day they are installed. Once a leak occurs it does not self-heal. It may grow over time or remain constant, but it will continue to leak. A lot of the leakage reduction in the late 1990s was due to efforts to fix a backlog of leaks that potentially could have been running for many years. However, leaks continue to break out and to grow, leading to an increase in leakage, and this has become known as the 'natural rate of rise'. A key consequence of this is that every day leaks need to be found and fixed to hold leakage at a steady level. To drive leakage down, the sector must repair a backlog of running leaks and reduce the time leaks are running.

Within the water distribution system there is a large variety of leaks, from small weeps and seeps, to very large leaks, some of which appear as bursts on the ground surface, but others can remain undetected for a long time. An implication of this, is that there is likely to be many very small leaks in the system, which will be challenging to find and fix; these contribute to what has become known as the background or base level of leakage. This is the leakage level that might be very difficult to reduce using current detection technologies and techniques, without replacing or relining pipes i.e., improving the condition of the asset.

The amount of water escaping from leaks can be minimized by reducing the pressure inside the pipes, but customers expect a certain level of water pressure and in areas with hills and mountains the water needs to be pumped over these, leading to higher pressures. Some boiler systems in homes and commercial premises also rely upon a minimum pressure to operate, and minimum standards are in place to ensure that customers receive sufficient water pressure. However, managing the water pressure in the system is a key part of managing leakage.

Pressure transients or surge, is a large and rapid pressure variation and is similar to water hammer in a domestic plumbing system. This can be caused for example where valves are opened or closed too quickly and can be due to the operational actions of water companies or the actions of large commercial customers where water is taken rapidly from the system. This can also cause leaks to break out, so maintaining calm networks is seen as increasingly important.

Where does leakage occur and who is responsible?

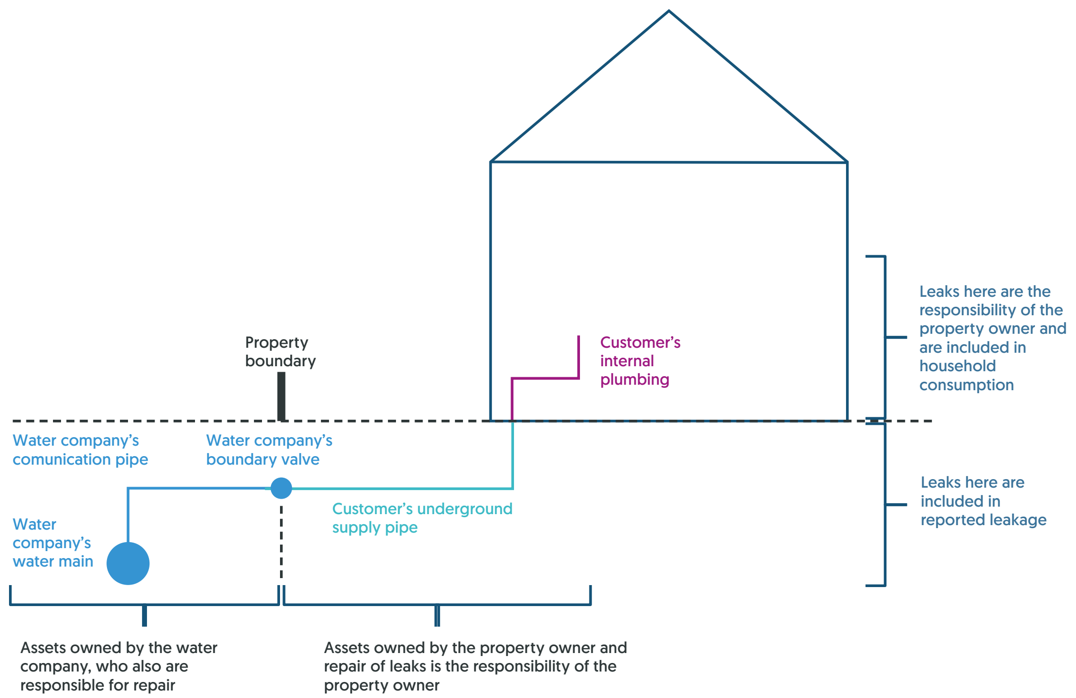
Water can leak from any point in the distribution system. The distribution system can be defined as the network of pipes and reservoirs that takes potable water from the water treatment plant through to the consumers' property. It includes:

- Water pipes, which include trunk or transmission pipes, and smaller distribution pipes. These typically range from 1000mm to 70mm in diameter.
- Communication pipes that connect the water main to the stop cock at the boundary of the property. These are typically 25mm to 40mm in diameter.
- Customer supply pipes that connect the stop cock at the customer property boundary to the property itself. These are typically the same diameter as communication pipes.

Water companies own the water pipes and communication pipes, and there are about 350,000km of water main in England and Wales, supplying about 26,500,000 properties.

Customer supply pipes are owned by property owners (which is different to other utilities); however, the water companies must include leaks on customer supply pipes (Figure 1.2) in reported leakage. Where revenue meters are installed, they are commonly located at the water company boundary valve. We estimate that there are about 230,000km of customer supply pipes in England and Wales, and the leaks on these assets account for approximately 25% of leakage. Leaks from plumbing pipes and devices (such as taps, WCs, and pipes) inside of the property are the responsibility of the property owner. A small allowance is made for internal plumbing losses in the estimation of leakage, however recent studies have shown that internal plumbing losses are significantly greater than previously estimated.

Figure 1.2 – The UK water network ownership and leakage responsibility



Plumbing losses can be difficult to differentiate from supply pipe losses, as the flows can be similar; and this is the case even if an external meter is fitted. An additional challenge with customer supply pipe leaks can be the time it takes to either get access to the pipe or encourage the customer to fix the leak, leading to longer leak run times.

In 2013-14 Defra[7] consulted on transferring ownership of customer supply pipes to water companies. This identified a range of benefits including the maintenance and the increased opportunity to reduce leakage. However, the consultation concluded that whilst there were benefits to be gained, there was less certain evidence about the range of potential impacts on water bills for various customers, and therefore there was no further work carried out to transfer ownership.

7 DEFRA. Consultation on the future management of private water supply pipes - A summary of responses to the consultation and government reply, July 2014

1.3 The role of Scotland, Wales and Northern Ireland

The route map presented covers only the water companies in England. However, the interventions that are presented are also relevant to the situation for Scotland, Wales and Northern Ireland, and could be adopted to assist with the reductions that they have each proposed over the coming years. With different regulators to the English companies there are a number of factors that would impact the scenarios presented in unique ways that will need to be investigated at a country level to ensure that the interventions proposed are suitable.

SECTION 02

How To Use This Report

2.1 Proposed framework

This report is designed to inform and assist the development of leakage business cases, plans, innovation projects and other initiatives over coming years. It outlines the key priorities and interventions for the water industry as a whole, individual companies, and other bodies like government.

It also outlines the potential costs involved in achieving the targets the industry has been set. It doesn't however provide a guide for water companies to achieve these targets, this is for two reasons:

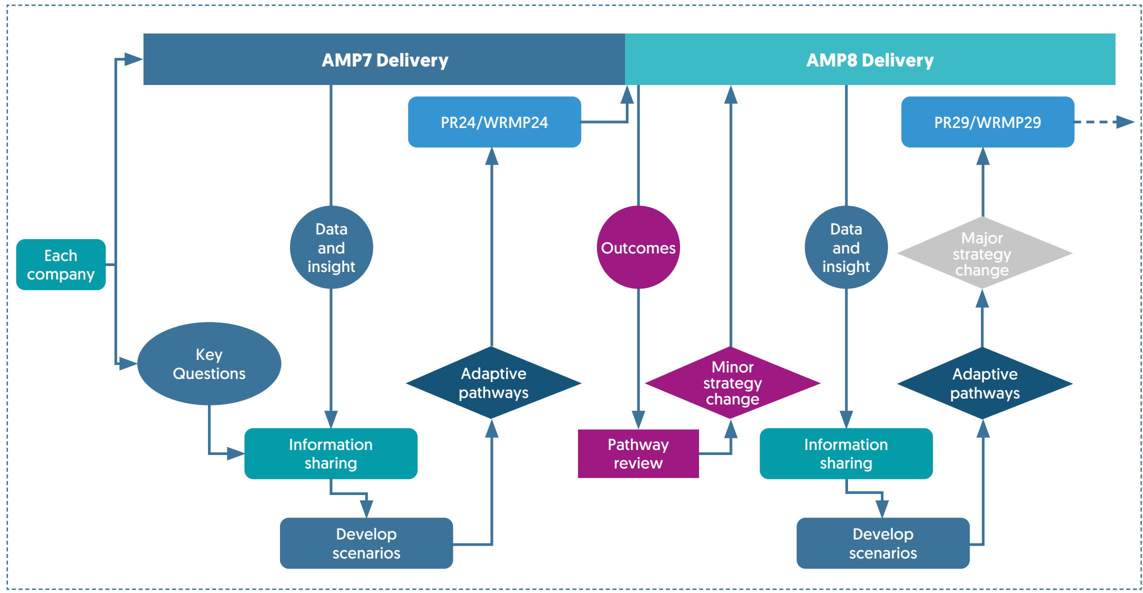
- All water companies are different, have different environmental and physical challenges that impact leakage levels as well as varying starting points. Hence there is no one right way to reduce leakage that would be suitable and efficient for all companies.
- Due to the historically low leakage levels that will be achieved there is a great deal of uncertainty. The plan must be adaptable to the additional changing climate, social and economic pressures that may be applied to water companies in the future.

A high-level framework that is suggested as the key to developing the leakage route map to 2030 and beyond to 2050 for all companies is presented in Figure 2.1. Vital to its success is the delivery of the AMP7 leakage reduction commitments made by all companies at PR19.

Knowledge and information-sharing is an important requirement, but so too is the need to resolve some of the key questions posed by this report. Those questions include the need to develop a better understanding of background leakage levels, and the solutions for reducing them. Companies also need to consider the risk of increased losses from customer-side leakage. We then suggest an adaptive pathway process that each company can follow to achieve their most appropriate strategy given their conditions. This is an iterative process that ensures the most appropriate pathway is selected, using the price review process, and Water Resource Management Plans, to make major course. This approach matches the approach outlined by Ofwat in their recent discussion paper for strategy setting in PR24[8].

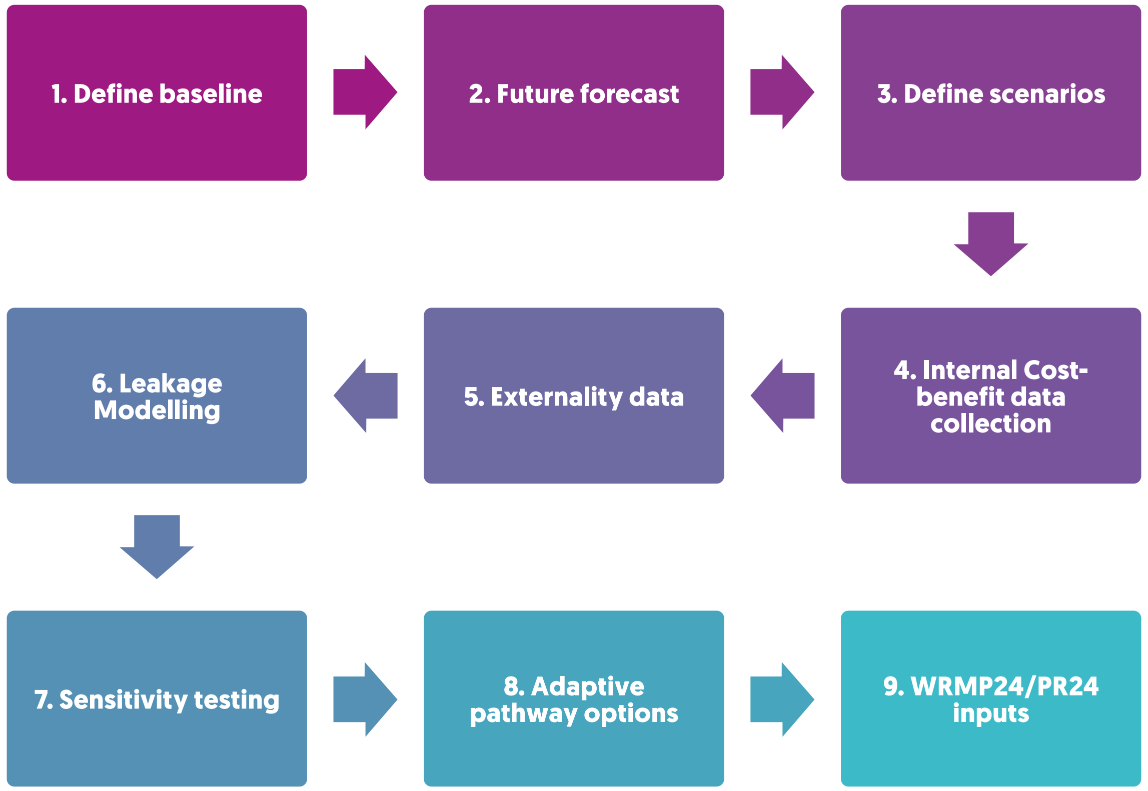
[8] OFWAT, PR24 and beyond: Long-term delivery strategies and common reference scenarios, November 2021

Figure 2.1 – Framework to achieve leakage reduction



The adaptive pathways process part (dark blue) in the above diagram is set out in greater detail in Figure 2.2.

Figure 2.2 – The adaptive pathway process



1. Define baseline

There are a number of considerations that are important in terms of developing a long-term leakage route map. One of the potential risks around the current WRMP process is the lack of attention paid to setting the leakage baseline. The water resources planning guidance[9] states that leakage shall not increase from current levels, and the current level of leakage is often an assumption that is made to represent the baseline.

For long-term planning purposes it is necessary to define the baseline and understand how short and long-term weather impacts may influence leakage performance.

2. Future forecasts

The population growth forecast over time is likely to result in an increase in the length of network, and if new networks are not leak free, this is an upwards pressure on leakage over time. Further upward pressure may be assessed in terms of the risk associated with the asset deterioration of supply pipes or distribution networks.

An additional upward pressure may be the public desire to reduce the number and frequency of excavations in the public highway, and this may manifest through Local Authorities and Councils introducing greater costs and penalties for unplanned works in the highway.

Downward pressure on leakage might include improvements in efficiency or a reduction in repair costs due to a technological advancement, or an increase in skilled workers that can carry out additional active leakage control to locate hidden leaks. Overall, the upwards pressures on leakage may be more certain than the downward pressure, however a balanced approach should be undertaken and then any leakage interventions required in order to stand still should be quantified, before being “selected” as options to reduce leakage below current levels. This step is considered important in avoiding a potential pitfall where low-hanging fruit options need to be considered to offset future increase in leakage rather than being able to reduce it in volumetric terms.

[9] Environmental Agency. Water resources planning guideline, July 2021. www.gov.uk/government/publications/water-resources-planning-guideline/water-resources-planning-guideline#section-6--developing-your-demand-forecast

3. Defining scenarios

The scenarios set out in section 4.3 are suggested to be considered in the context of:

- The costs and benefits associated with 40%, 50% and 60% reduction from current levels of leakage. This is to highlight any significant step changes in costs as the industry moves beyond the PIC.
- The potential impacts of climate change and more extreme weather.
- Mid, low and upper estimates of costs to reflect potential future changes such as significant reductions in repair costs due to new innovative technology and techniques, or availability of lower cost sensors.
- Consideration in relation to potential longer-term optimism in relation to factors such as the adoption of customer supply pipes, metering and especially smart metering policy and other factors that may enable leakage reduction.
- The opportunities for cross-benefits for other programmes, such as tackling water quality, consumption, interruptions to supply and environmental impact.

These scenarios would ideally be used to provide WRMPs and regional planning with robust options associated with the reduction of leakage that are deliverable in the longer-term.

It will be necessary to fund innovation in order to obtain continuous improvement and derive the breakthroughs that will be needed to help ensure the long-term reduction in leakage is affordable for customers.

4. Internal cost-benefits data collection

This will link to the resolution of the “key questions” and an appropriate way of sharing information in terms of the success or failure of different techniques or technologies. Internal costs should factor in additional benefit such as levels of service to customers, water quality and companies will need to align the assessment of leakage scenarios with wider business planning processes.

Robust cost and benefit data should be collected with cost curves for different options being developed.

5. Externalities

The costs and benefits associated with externalities should also be considered however with care to avoid double counting of benefits. The wider WRMP and business planning processes may be the appropriate place to make holistic decisions, factoring in benefits such as carbon reduction.

6. Cost curves and modelling

Robust cost and benefit data should be collected with cost curves for different options being developed. These should be used to determine the costs and benefits of the different scenarios. Any offsetting of increases due to upward pressure on leakage such as network growth will need to be offset before utilising any options to reduce leakage via the adaptive pathways.

As leakage levels reduce and the levels of leakage reach historical lows, the certainty around costs will reduce. The industry must develop a method of informing all companies of the potential costs of these reductions, without breaching competition law.

7. Sensitivity testing

Sensitivity testing should be undertaken to demonstrate which inputs and assumptions the scenarios are most sensitive to. In relation to costs the increasing uncertainty around the costs assessments will also need to be considered.

8. Adaptive pathway development

The development of adaptive pathways will depend on the relative position of a company to background levels of leakage, the characteristics of the network and its DMAs and other factors such as pressure, topography and ground conditions along with the company maturity with respect to progression towards a particular pathway in AMP7.

It will be necessary to define the tipping points for individual companies, and consider the potential strengths, weaknesses, opportunities and threats (SWOT) of each pathway. The company specific costs and benefits derived will help companies in determining which pathway to take, however a robust approach to decision making is a potential consideration for regulators and water companies to consider to ensure consistency in approach.

9. WRMP24/PR24

The inputs into these plans should be robust and fully costed, with an appreciation of the risks and opportunities associated with the preferred pathway.

It is considered necessary to resolve answers to a number of key questions in AMP7 as companies start to reduce leakage further, summarised in Table 1.

Table 1 – Key commitments for the industry in AMP7

Date	Commitment	Requirement
Sep 2022	Improve quantification of background leakage and understand if it can be targeted for asset renewal	The adaptive pathway chosen will be extremely sensitive to the level of background leakage. The level of background leakage could have a significant bearing on the most cost-effective pathway taken, and a further consideration is what to effectively do about background leakage, and if it is indeed at all possible to target asset renewal to reduce it.
Sep 2022	Improve quantification of customer side leakage and consider the risk associated with asset deterioration	The presence of customer side leakage as part of total leakage represents a significant "known unknown" as limited asset records or information is available. Achievement of the PIC and longer-term reductions of leakage may be very dependent upon what happens with customer side leakage. Companies with large volumes of smart meter data will need to lead, as this provides the best intelligence in relation to customer supply pipe leakage volumes and breakout rates.
Sep 2022	Quantify the scale of supply chain resource constraints	The risk of supply chain resources not being sufficient to support the long-term pathways. This is could be in the provision of technology to assist water companies, but also the people and expertise needed to assist the water companies in these endeavours.
Sep 2022	Deriving benefits from smart metering and smart networks	Robust quantification of what works in different locations and conditions to understand how investment options change the economics of managing leakage, and quantifying what, if any, the benefit is in terms of reducing policy minimum leakage.
Dec 2022	Developing asset renewal selection and modelling based on leakage and asset health	Traditionally leakage strategies and asset rehabilitation strategies have been separate, however to achieve the long-term aims in reducing leakage, a holistic approach is needed to determine the most effective balance between short-term solutions and long-term ones.
Dec 2022	Development of an industry standard or code of practice on how to lay new network without any leakage.	As population growth occurs, the overall length of networks being managed will increase, and this can be an upward pressure on leakage. Laying a completely leak free new network is an important element of achieving the PIC and long-term aims, as well as being necessary for an asset focused strategy. Currently the industry lays almost leak free networks, but to achieve the targets as set out this would need to improve.

2.2 The adaptive pathway

In deriving an adaptive pathway for leakage, there are two key stages:

1. **Adaptive pathway analysis** – linking the range of economic costs and benefits, with a review at least once every AMP cycle, where there is a shift in strategy if challenges or costs increase above an acceptable level.
2. **Dynamic adaptive policy pathways** – where the scenarios are assessed in terms of metrics and tipping points that may be related to external developments e.g. climate change, significant technological breakthrough.

There are considerable variations around both the scenarios and interventions from which they are composed and there is a virtually limitless number of minor variations that could be taken by companies.

The scenarios produced for this route map provide some high-level categorisation that provide a range of different outcomes based on a continuation of policy exhibited from the recent past, through to ambitious data and asset focused improvements and progressive policies.

The key steps required in developing company or regional specific plans are:

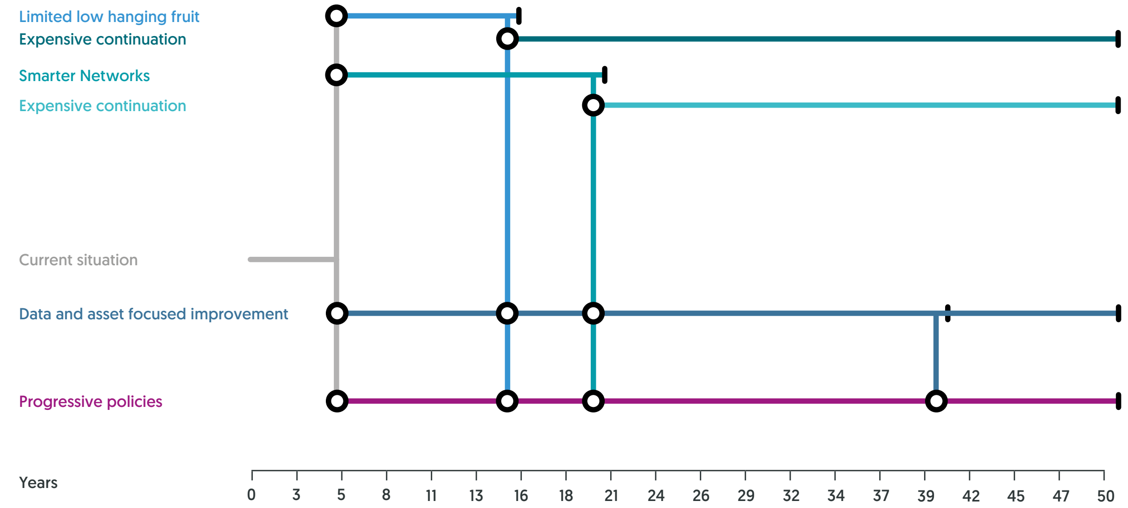
1. Resolving the key questions in relation to background leakage, laying leak resilient new networks, quantification of customer side leakage, understanding supply chain and resource constraints, improvements in targeting asset rehabilitation and deriving robust benefits from smart metering and smart networks.
2. Improving the way information is shared, specifically in relation to success and failure of new process and technology, hence lessons can be learnt by the industry more quickly.
3. Developing company specific scenarios and setting out the criteria for the tipping points in relation to adaptive pathways.
4. Planning for a range of different futures, from extreme weather due to climate change through to technological breakthroughs that lower the cost of smart networks solutions.
5. Identifying the additional and cross benefits of the interventions made for leakage have on other areas of the network such as water quality (e.g. potentially removing lead supply pipes), interruption to supply (e.g. more real time data on network performance), consumption (e.g. universal metering) and environmental impact (e.g. the improvement of natural water habitats due to the reduction of abstraction).

An example of adaptive pathways for leakage is demonstrated below (Figure 2.3), with a number of tipping points (black lines) illustrated where continuation would be considered unacceptable or prohibitively expensive. As well as the ability to change to a new pathway at interchanges (black circles).

Subject to improving the estimate of background leakage, there is a potential risk that achieving 50% reductions from current levels of leakage by 2050 may not ultimately be possible without some radical changes and progressive policies.

This statement may vary from company to company, and is highly dependent not only on the level of background leakage, but also upon how effective different solutions can be at reducing background levels of leakage. It may be possible over time, to improve the understanding of the relationship between asset condition and background leakage, however the converse may also be true, and for the long-term aims to be possible it may be necessary to renew networks where high background leakage is present. Unless these areas of network can be identified, asset renewal may be prohibitively expensive.

Figure 2.3 – An example of a leakage adaptive pathway



SECTION 03

Historical performance and current trajectory

3.1 How leakage is estimated

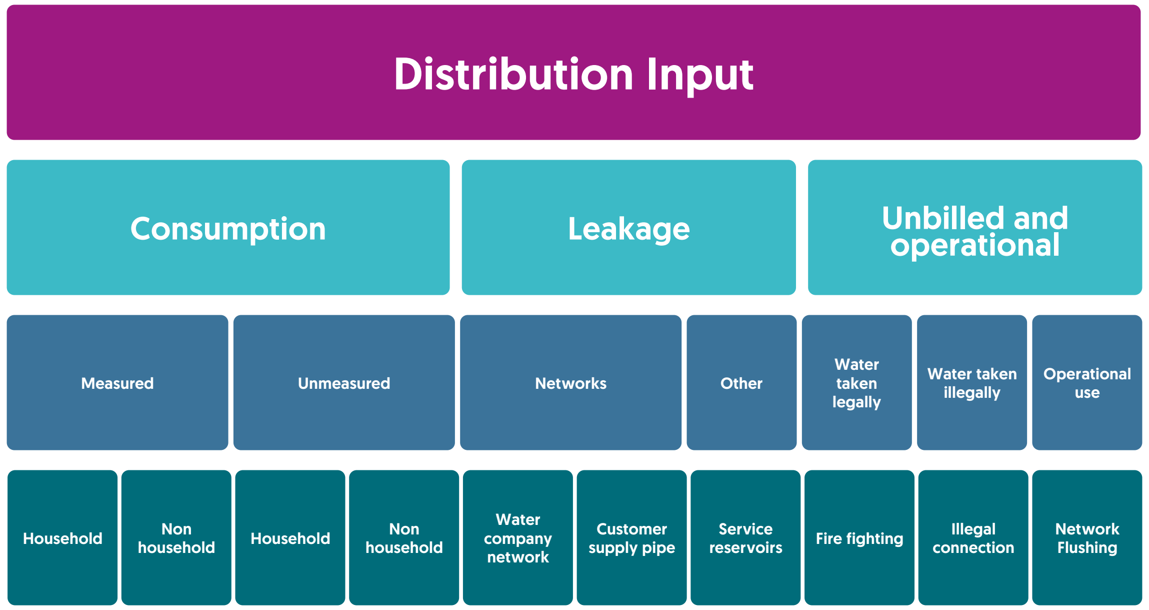
The majority of water meters installed in the UK since privatisation of the water industry, are manually read on a cyclical basis that varies between a few months and a year.

Recent advances in technology have resulted in smart meters that can provide data much more frequently. Before this, obtaining an up-to-date estimate of consumption by customers in domestic or commercial properties on an hourly, weekly, or daily basis was not feasible. A top-down water balance at a zonal or DMA level, would therefore typically only provide an average consumption volume from historic meter reading information. As consumption patterns change, this would result in any changes in terms of the water that is input to the zone, manifesting as potential leakage. As factors such as the economy and weather conditions can have a significant bearing on consumption, the bottom-up method was developed.

The top-down method

The top-down method for estimating leakage effectively takes the volume of water produced and input into the system after treatment (known as Distribution Input) and subtracts volumes and estimates for consumption, unbilled use and operational use. The diagram below is a simplification of the different components, as there are also considerations to be made in relation to the under-recording of meters and consumption estimates that need to be taken into account.

Figure 3.1 – Top-Down Water Balance Components



The top-down estimate is used throughout the world in various guises, however in the absence of universal smart metering, it is not sufficient to provide a robust operational tool to react to changes in leakage on water networks.

The bottom-up night flow method

This method was developed to provide greater insight into leakage estimates and trends, to support the targeting and deployment of resources to locate hidden leakage through active leakage control. DMA flow data from the early 2000s onwards could be collected using data loggers with mobile phone technology incorporated, providing data on a daily basis as opposed to meter reading cycles that would be carried out every few months. The industry focused on the flow during the night, as this is when there is generally the least activity from customers in terms of consumption and coupled with more frequent data from DMAs, provided a methodology to better understand leakage levels and trends.

The night flow losses method pioneered in the UK, calculates leakage based on the minimum flow that occurs during the night. This is calculated at the sub area level where the flow into and out of the area is measured (i.e. a DMA or zone). It uses the principle that l eakage represents a much greater proportion of the flow observed at night, than it does compared to the consumption and flow during the day and can therefore provide a more reliable estimate of leakage in the absence of widespread smart metering data. The method measures the flow for a set period during the night and then subtracts assessments of the night use of households and businesses to provide an estimation of leakage.

Leakage is influenced by pressure and this can vary throughout the course of a day due to the characteristics of water networks and pressure control regimes. The leakage estimated at night is adjusted to a daily estimate using a pressure correction factor.

The sub area used is either a District Meter Area (DMA) made up of typically around 1000 properties, or large zones that are fed by a specific reservoir or treatment works.
The minimum night flows for all the sub-areas are summed to a company level, and this figure is used as the leakage value, including an estimate for trunk mains and service reservoir leakage (if this is not accounted for already). This is calculated daily and then aggregated over the year.

The UK hybrid approach

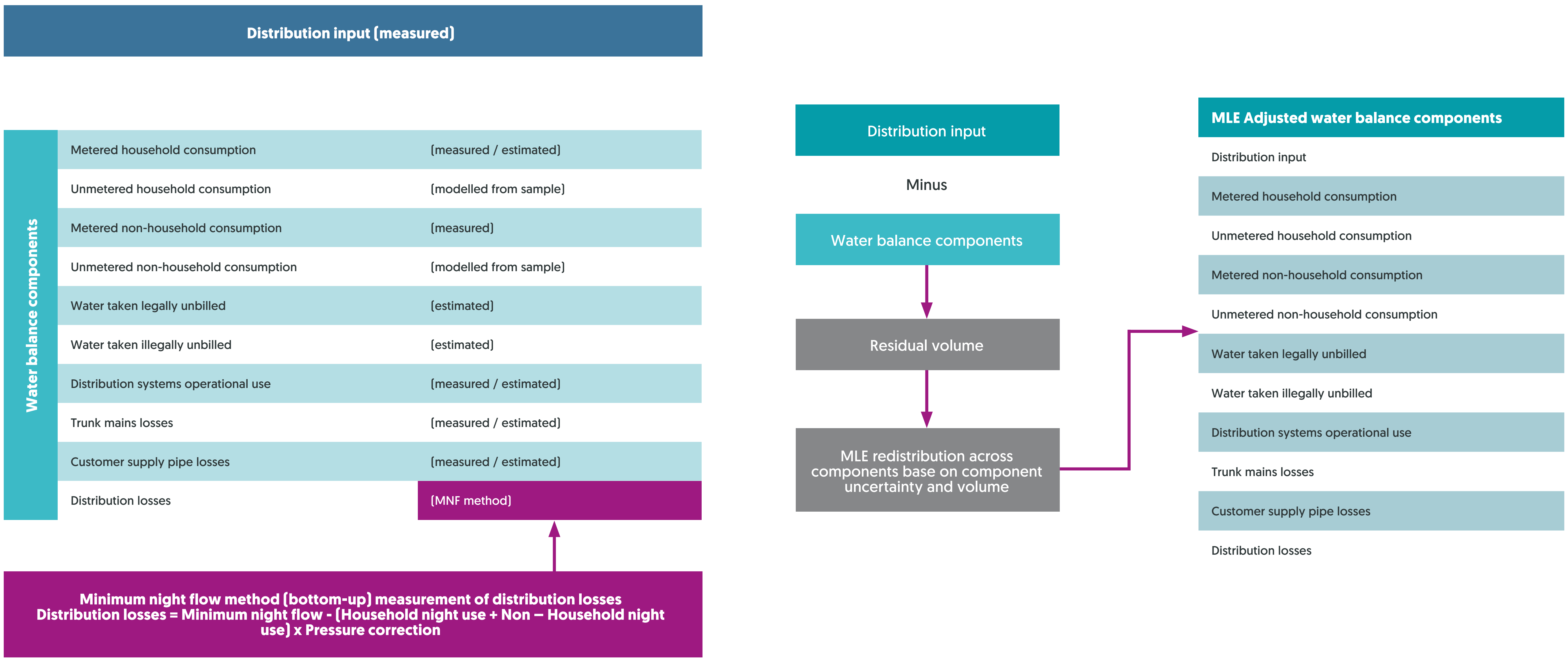
In the England and Wales only about 55% of properties have a metered consumption, however this varies considerably across the UK where water stressed areas tend to have high meter penetration driven by the need to reduce the demand for water. In some companies, there are over 90% of properties metered. In the rest of the UK most properties remain unmetered. This means that the consumption from properties has a higher uncertainty, potentially resulting in a bias in the top-down water balance derived leakage. Therefore, the UK uses a hybrid of the two methods and this provides a more robust approach for estimating leakage than is observed in many countries around the world as both the top-down and bottom-up estimates are expected to be within 5% of one another. This has been in place for regulatory reporting since the early 2000s.

The night flow losses method is used to calculate the DMA or reservoir zone level leakage, and then this is inserted into a water balance. This allows an assessment of all the components of the water balance, which allows the sum of all components to be subtracted from the distribution input to leave a residual. It is not possible to measure all the components with complete certainty, therefore when summing the components they are unlikely to match perfectly with distribution input volume. The residual volume results from the uncertainty bias in all of the water balance components. This residual volume is distributed across all the components based on the uncertainty and volume of each component; this process is known as the "maximum likelihood estimation" (MLE) method.

In the UK, leakage is reported as a yearly value once the MLE method has been applied. Methods for calculating each of the assessments should be consistent with previous years and the methods used when the targets were set. When a significant method change occurs then the target is re-calculated, hence most methodology changes have occurred as part of the business planning process.

Although the overall method used is similar between all the companies, the methods used to calculate individual components may vary. This process is set out graphically on the next page (Figure 3.2). The industry has to comply with reporting guidance that is published by Ofwat, and there is within this some flexibility to ensure that the best use of available data, whilst maintaining an overall framework for consistent reporting across the industry.

Figure 3.2 – The MLE process used by UK water companies



UK leakage figures are calculated in a different way than the typical international methods that are usually just based on a variant of top-down water balance. There is often an incorrect comparison made between non-revenue water that can include consumption that is not billed, and UK leakage. Non-revenue water does not include the leakage from customer supply pipes, while it does include consumption that is not measured, and the latter is not deemed to be leakage in the UK whilst the former is included. Hence direct comparisons between the UK and international values must be made carefully and heavily caveated, bearing in mind such potential differences.

Consistency reporting for AMP7 (2025 -2030)

During AMP6 the industry investigated the variability in how leakage levels were reported across England and Wales. This led to a new best practice document being developed for leakage reporting to improve the consistency between companies.

This process has now been implemented by Ofwat and water companies in England and Wales for AMP7. The new method still uses the hybrid approach, but some of the detailed processes have been made more consistent[10].

3.2 Historical performance

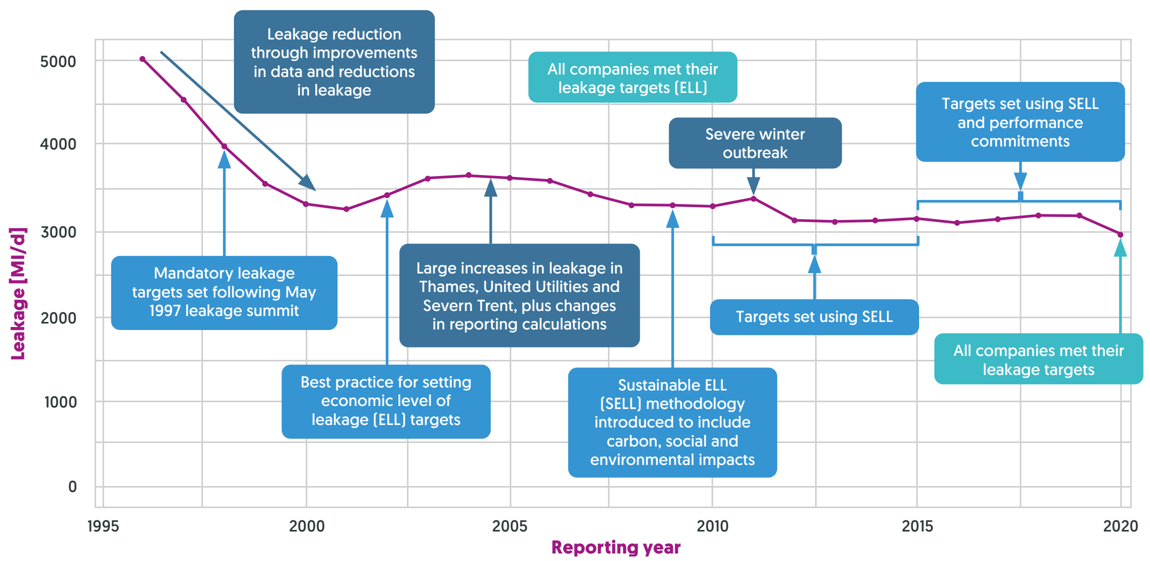
England and Wales

The schematic in Figure 3.3 shows that England and Wales have reduced their sector leakage by 40% from 1996 to 2020. As mentioned in the introduction, mandatory leakage targets were set following the May 1997 leakage summit.

These helped to drive leakage levels down to an initial minimum in 2001. Some of this decrease was through reducing water leaking from pipes, some was due to improvements in measuring leakage following the best practice guidance in the Managing Leakage series[2] of reports produced in 1994.

[10] Ofwat. Reporting guidance – leakage, 2018. www.ofwat.gov.uk/publication/reporting-guidance-leakage

Figure 3.3 – Leakage profile for England and Wales from 1995/96 to 2019/2020



In 2002 best practice was produced on setting targets using the economic level of leakage or ELL. From 2001 to 2005 there was an increase in sector leakage. Leakage in Thames increased by 283 Ml/d, in United Utilities it increased by 50 Ml/d, and in Severn Trent leakage increased by 174 Ml/d.

In 2005 to 2006 Thames made a method change to the leakage calculation that decreased reported leakage by 30 Ml/d, whilst Severn Trent changed their calculation which increased leakage by about 20 Ml/d. These changes illustrate the difficulty in quantifying leakage and differentiating between leakage and the volume of water used by customers during the night period.

All companies in England and Wales met their economic level of leakage from 2007-08, through to 2010-11, when 6 companies (Anglian, Dŵr Cymru Welsh Water, Northumbrian North, Severn Trent, Southern and Yorkshire) failed to meet their targets. This resulted in an increase in 2010-11 due to an extreme cold weather event during the winter.

After this, leakage levels reduced towards the new sustainable ELL targets by 2014-15, with most companies meeting their targets from 2012 through to 2016. For the period from 2015 through to April 2020 there was an increase in the level of leakage due to a few companies failing their leakage targets (Thames and Northumbrian in 2017, Southern in 2018 and Hafren Dyfrdwy, Thames and Affinity in 2019). All companies met their targets by the end of the reporting year in 2019-20.

Scotland

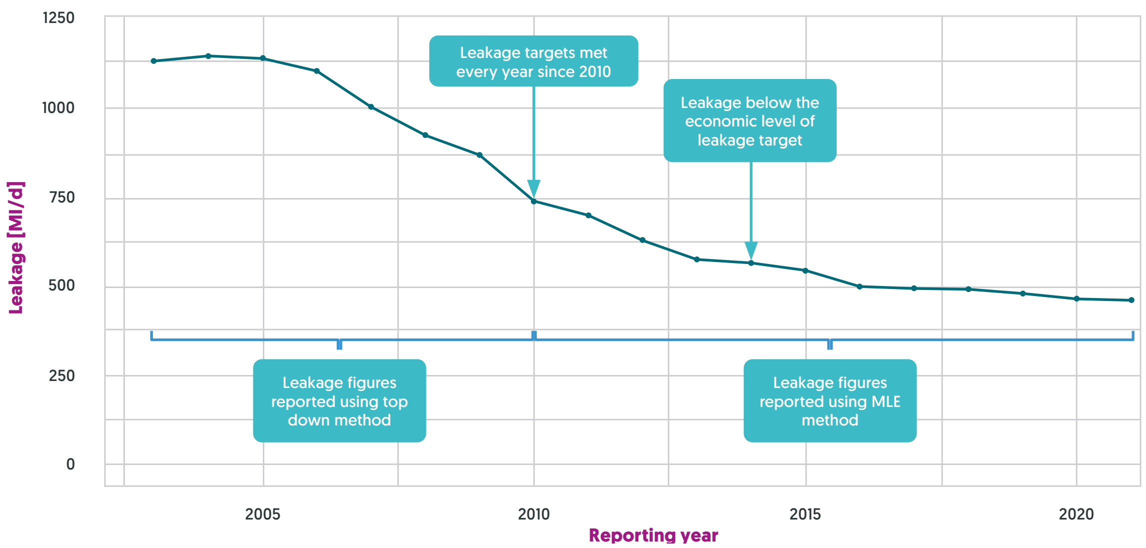
Figure 3.4 shows that Scotland has reduced its level of leakage by 60% from 2005 to 2020 (this is based on Ml/d reported values). It appears Scottish Water has outperformed England and Wales based on this measure. However, leakage, when normalized by property and km of main, started from a much higher level than in England and Wales (Figure 3.6).

Additionally, Scottish Water's program of leakage reduction did not start until 2005, and this program was able to take advantage of the best practices, skilled resources and mature supply chain that had been built up since 1995 tackling leakage in England and Wales.

Scottish Water have consistently met or exceeded their targets every year since 2009-10. In 2010 the reporting method was changed to use the hybrid MLE method.

In Scotland, the economic level of leakage (ELL) was first met in 2013-14, and in Scotland the ELL target is set as a range with a minimum level of service expected and an upper target.

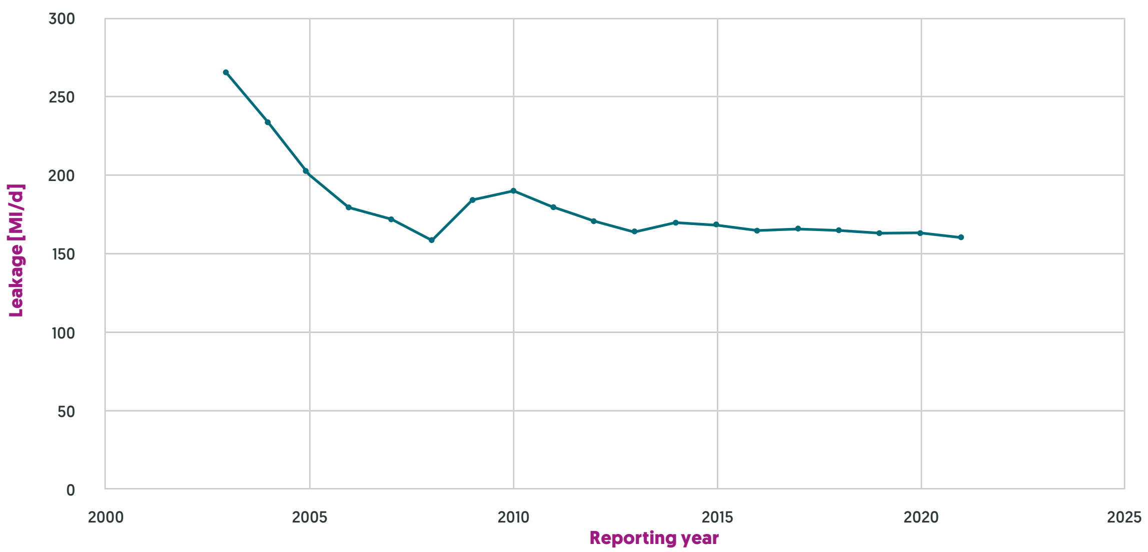
Figure 3.4 – Leakage profile for Scottish Water from 2002



Northern Ireland

Figure 3.5 shows the reduction of leakage from Northern Ireland Water. Following a profile similar to the English and Welsh companies they have reduced their leakage by almost 40% from 2003 to 2020. As with the rest of the nations, they saw initial large leakage reductions, which have flattened in recent times.

Figure 3.5 – Leakage profile for Northern Ireland Water from 2003

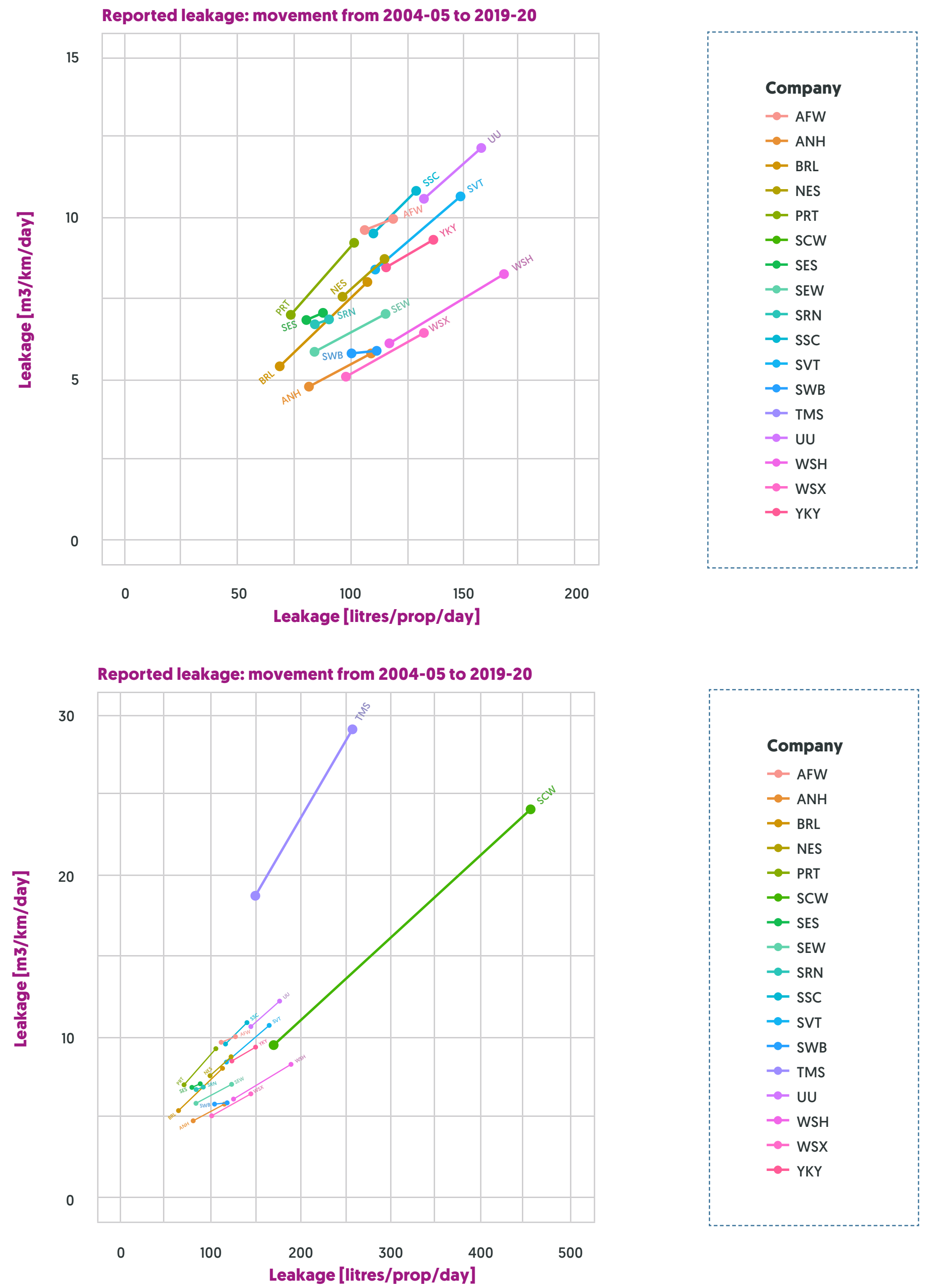


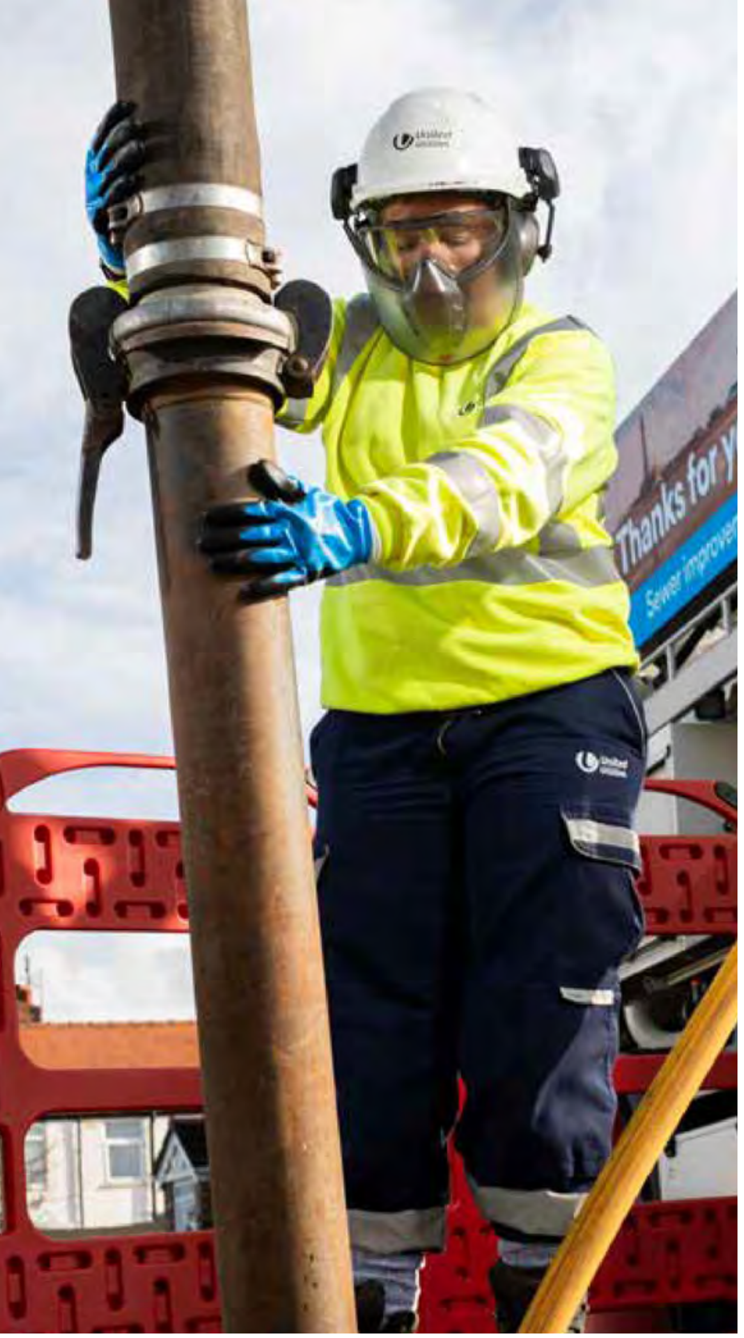
Leakage reduction from 2004 to 2020

The graphs in Figure 3.6 present the reported data in a different way, expressed in terms of network density i.e., the number of properties per unit length of main.

The regulatory Ml/d volumetric figures presented in Figure 3.3 and Figure 3.4 have been converted to litres/property/day and m3/km/day respectively shown on the horizontal and vertical axes on the two graphs.

Figure 3.6 – Comparing reported leakage between 2005 and 2020. (All companies are shown on the left with the bottom left corner expanded on the right)





These graphs show the movement in these two performance indicators from 2005 to 2020. Each company has 2 points connected by an arrow; the upper right point is the leakage in 2004-05, the lower left point is the leakage in 2019-20.

Figure 3.6 shows several interesting observations. Firstly, in the graph on the left, there is a cluster of companies in the lower left-hand quadrant of the graph. These are all the English and Welsh companies, except Thames Water. This section of the graph is then shown in greater detail on the right-hand side graph.

They all start from different positions in 2004 and reduce leakage by differing amounts to 2020. This indicates that leakage varies considerably between companies, which will be related to the complex factors that drive leakage. In 2020 the lowest levels of leakage are achieved by Anglian Water and Bristol Water (these two are closest to the lowest left corner of the graph).

Note if all English water companies were at this frontier, then leakage would be approximately 1,600 Ml/d (the target figure for 2050 is 1,500 Ml/d).

Thames is a clear outlier to the other companies in England and Wales. Despite the significant progress to reduce leakage from 2004 to 2020, leakage has always been much higher when compared to both the property and length of main metrics. Most of the properties in Thames fall into the London area, which has a high population density, a high network density, high traffic congestion, different mains lengths, and some of the oldest pipes in England. These factors, and potentially others contribute to the higher leakage level. Significantly, if we were to look at the zones outside London, then they would have performance similar to other water companies. For example, the Swindon-Oxford Water Resource Zone leakage in litres/property/day is around 16% lower than in London.

Scotland's performance shows the biggest reduction, but the starting point in 2004 is higher than all other companies in England and Wales (except for Thames). By 2020 Scotland's leakage is in amongst the group of English companies. All companies have reduced leakage. There are differences in the amount of leakage reduced, most likely due to differences in factors driving leakage and active leakage control.

3.3 The UK water network

There has been a piped network in the UK since the Roman times, although limited. In the sixteenth century pipes systems existed in cities such as Leeds and Bristol. The "modern network" has been constructed over the last 150 plus years. The network grew during the Victorian Industrial Revolution where networks were limited to the large cities and owned by private companies.

The network grew through several acts of parliaments, specifically in the late 1940s when the water network was expanded to the countryside. Many of these early pipes were different forms of iron pipe joined together using several techniques. After this point the network began to grow more in line with the construction of new towns or cities as the UK population expanded and the manufacturing-based economy developed into a more service-based one.

In the 1950s PVC pipes began to be used as the post-war expansion towns grew, in places such as Swindon and Luton. In the late 1970s there were improvements in the PVC materials brought about by a number of premature failures in the early materials.

In the 1980s polyethylene pipe became the favoured material for new water pipes with fused joints that constructed in theory one continuous stretch of pipe. This increase in plastic materials for pipes, has had a significant impact on leakage detection as the acoustic methods used historically are less effective on these types of network.

The Water Act 1989 resulted in the current privatised regulatory regime that is seen today, with the Environmental Agency, Drinking Water Inspectorate and Office of Water Services (OFWAT) responsible for regulating different sections of the industry.

Since privatisation the water network has further expanded with new housing and commercial developments, but some of the poorer performing sections have also been replaced.

3.3.1 Comparison with international performance

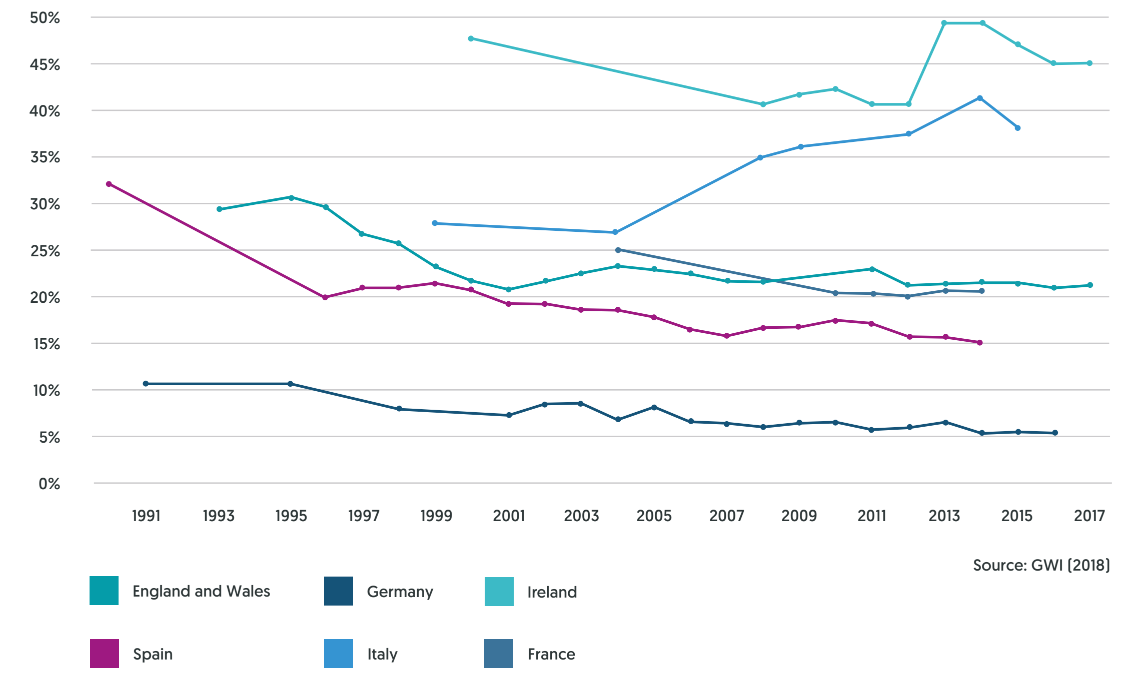
The rest of the world measures leakage in a different manner to the UK. The focus is far more on the non-revenue water, which makes direct comparisons difficult. In spite of this there are a number of studies that can be used to compare the UK with other countries.

Volumetric comparison (% of distribution input)

A Global Water Intelligence (GWI) market study[11] in 2018 looked at the percentage of non-revenue water compared to total distribution input (Figure 3.7). In addition, it is believed that this study included UK supply pipe leakage is therefore inconsistent with other countries, and if corrected would place the UK around the mean.

11 GWI. International Comparisons of Water Sector Performance, 2018 www.water.org.uk/wp-content/uploads/2018/12/GWI-International-sector-performance-comparisons.pdf

Figure 3.7 – Non-revenue water comparisons across Europe



That said England and Wales are similar to France, with Ireland being significantly higher and Germany being at 5%. Germany has invested significantly in its network over the past 70 years, and is also assisted by benign soils and favourable water chemistry when compared with the UK[12].

Figures also show that Japan was at 3.1% in 2008 on a similar metric. This has reduced from approximately 18% in 1980. Since then, 40% of the network has been replaced and nearly 90% of all the customer supplies. This replacement was driven more by earthquake protection rather than leakage but has also had an impact on the leakage levels.

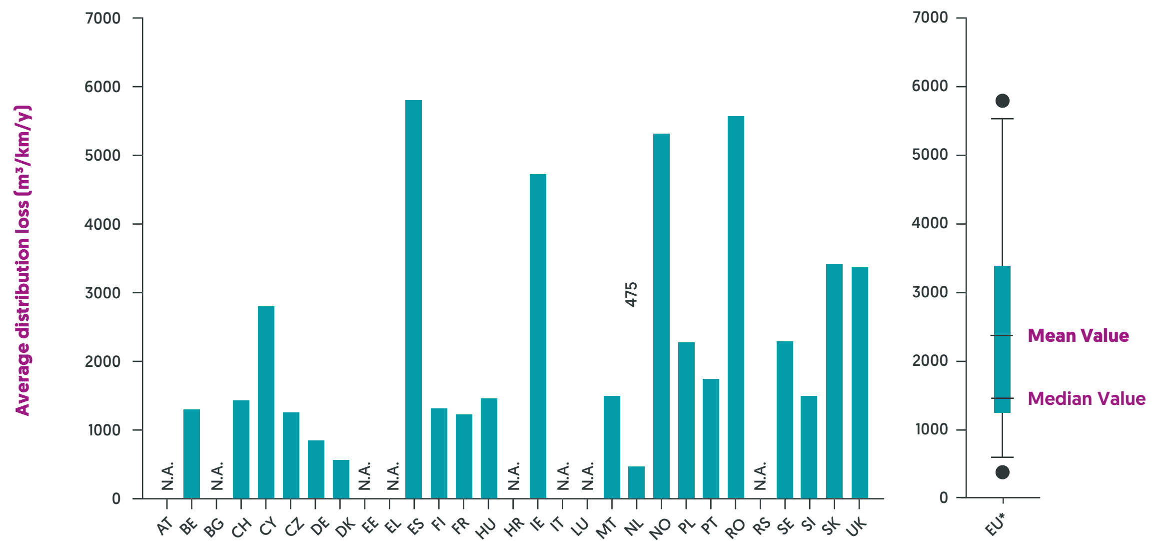
Representing leakage as a percentage of the total distribution input often provides a skewed view of the actual leakage performance and hence is not a good comparator. This is because higher consumption (and hence high distribution input) can lead to lower leakage values. This is particularly relevant in comparisons with countries that have water consumption that is significantly higher than the UK average, for example Japan and the USA.

Volumetric comparison (m3/km/year)

EurEau is a European Federation representing drinking and wastewater service providers from 29 countries. Their 2017 study[13] (Figure 3.8) showed the distribution losses for 22 of the members. The mean value for the sample was 2171m3/km/year, the 2020 value for the England and Wales was 3250m3/km/year.

[12] European Environmental Agency. (WQ06) Water use efficiency (in cities): leakage, 2009
[13] EurEau. Europe's water in figures, 2017

Figure 3.8 – Distribution losses per km for countries across Europe[11]



Ireland (IE) is seen to have a very high leakage value of almost 5000m3/km/year. This has been attributed to the limited funds that were available to replace the network and reduce leakage, as they did not charge for water. Since the formation of Irish Water in 2014, there has been steady progress as they adopt many of the practices that have been commonplace in the UK since 1990.

The Netherlands (NL) has a very low level of leakage approximately 500m3/km/year and is often highlighted as one of the best performers internationally. A study in 2006 by UKWIR showed there were a number of factors that caused the leakage levels to be lower than in the UK; sandy soils, flat topography, lower operating pressures, greater plastic pipe usage, the pipes being located in verges or pavement and the continuous lengths of service pipes between the main and the household[14].

The same study also looked at UK areas that had similar attributes to The Netherlands, i.e sandy soils, lower pressures and a high proportion of plastic pipes. These areas were seen to have a similarly low level of leakage when compared to the areas studied in The Netherlands.

Both of the volumetric comparisons show that the UK has above average values of leakage when compared to Europe. Germany, The Netherlands and Denmark are shown to be performing significantly better. However, all of these nations have networks that are not as old as the UK network as well as other factors (i.e. soil type, topography and water chemistry) that have led to the lower levels of leakage seen. The UK value also includes leakage from supply pipes, while this is not included in the other countries' values.

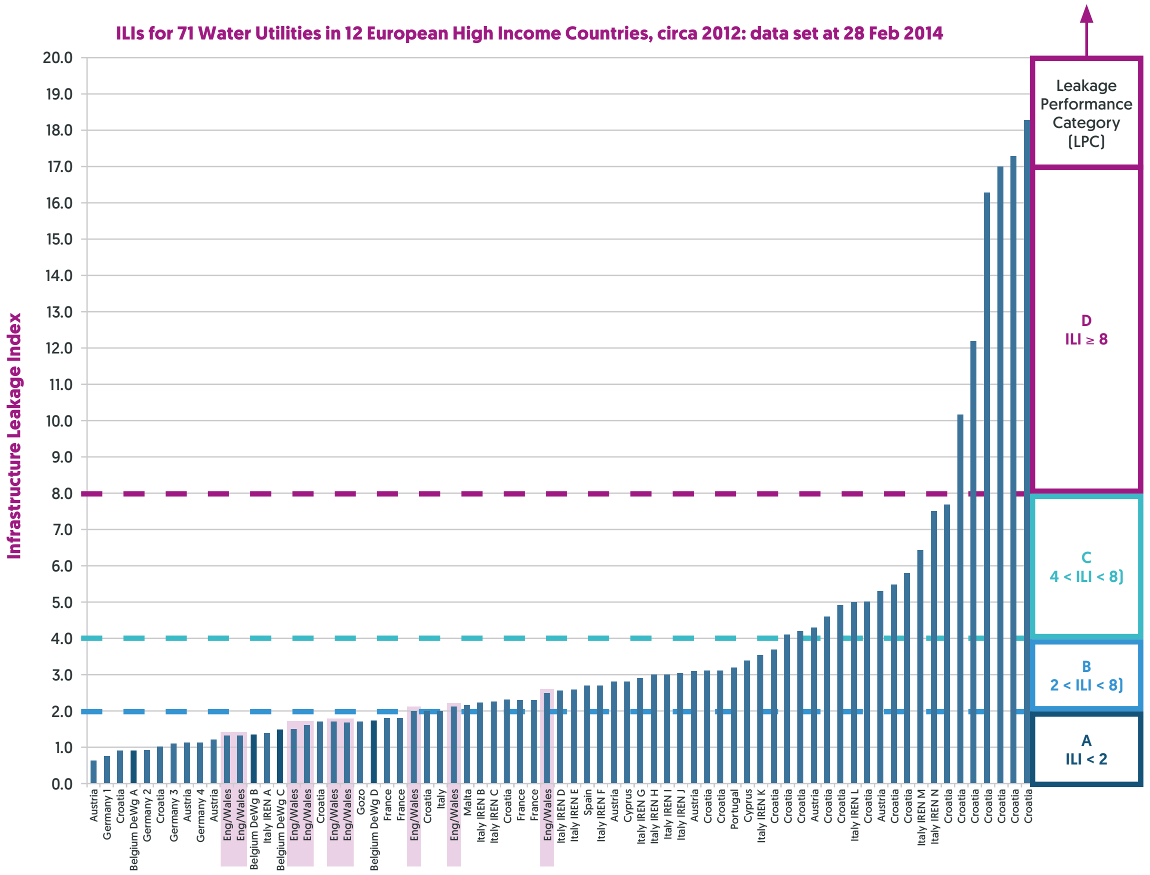
[14] UKWIR. Comparison of leakage practice and leakage levels in UK and Netherlands, 06/WM/08/34, 2006

Infrastructure Leakage Index (ILI)

The ILI is an empirical measure to look at the losses of a company compared to the theoretical minimum losses that would be expected on the network. The ILI uses the length of network, customers and pressure to produce the theoretical minimum losses that could be expected. The empirical values associated with each of these factors have not been updated for some time and have the underlying assumption that all networks behave the same and are in reasonable condition.

The UK companies in this 2014 study[15] show a much better performance than that seen in the volumetric comparisons (Figure 3.9). The reductions in leakage proposed in the PIC, would see these companies with an ILI lower than 1, i.e. below their theoretical minimum.

Figure 3.9 – Infrastructure Leakage Index seen across Europe[13]



Las Vegas Valley Water District Company had an ILI of 1.91 in 2014[16], which is similar to the UK companies presented. They are often highlighted as a company that is at the forefront of leakage detection and management. Their network is also much younger than the UK's due to when Las Vegas was built. In addition, they have been able to remove troublesome material cohorts. They have been able to replace 83% of early PE service pipes in a year (66,912), that had been unreliable. They also plan to spend $200 million dollars over the next decade on pipes and service pipe renewals.

[15] The LEAKSSuite Library. ILIs in Europe – update 2014, 2019 www.leakssuitelibrary.com/european-ilis
[16] AWWA. 2015 Validated Water Audit Data, 2015 www.awwa.org/Resources-Tools/Resource-Topics/Water-Loss-Control

3.3.2 How leakage is currently managed

The PALM model

The PALM model (or variations) has been used to explain the way that leakage is managed separating the "leak life cycle" into 4 phases:

- Prevent
- Aware
- Locate
- Mend

Prevent

The initial method for managing leakage, is not to allow leaks to occur in the first place. This is done through asset renewal, pressure management and network calming.

The benefits of this can be seen with the reduction in leakage seen in Japan after the network was completely renewed. Although not driven by leakage considerations, the levels of leakage seen in Japan are significantly lower than the UK, which can be attributed in part to the replacement of most of the Japanese network since the 1960s.

However, the replacement pipes must be installed correctly. There are a significant number of failures seen on new pipes. Quality control of new installations on the network needs to be in place to ensure that a leak-free network is produced. This needs to be in place for the networks laid by the water companies' contractors as well as third-party organizations that build networks that the water company will adopt.

Pressure management has been used in the UK since the 1980s. Reduction in pressure in the network removes stress from the pipe material (reducing failures) as well as reducing the flow of existing leaks. Management of pressure is done either on a strategic level, with pumps or large pressure reducing valves (PRVs) being used or in a local area where smaller PRVs are used in discreet areas.

Transients, which are pressure waves that can travel through the network, can also cause a significant amount of damage. Identifying and eliminating the cause of transients is potentially difficult, as they can be easily caused by third parties. However, the installation of newer designs of pumps and values, as well as training staff on how to operate them, can reduce the shocks that cause the transients, saving cost into the future. Working with customers where transients are identified and assisting them to modify their practices can also assist.

Aware

Once a leak has arisen the area where the failure occurs needs to be identified. For most leaks this is the longest period of its "life cycle". As part of the initial drive to reduce leakage in the early 1990s, companies constructed a number of District Meter Areas (DMAs) to assist with this. These DMAs broke the network into discreet areas of typically around 1000 properties. The flows into and out of a DMA are measured and any changes at night (when leakage is the dominant flow) are identified as potential areas for leakage investigation.

Recently these methods of analysis have become more sophisticated with AI and machine learning techniques starting to be used, to reduce the awareness time. As there is up to 30 years of daily time series data available, these techniques are starting to demonstrate their efficacy

This approach of proactively looking for leakage is known as active leakage control (ALC). When a company waits for a leak to break to the surface and be reported by a customer this is known as reactive leakage control. It should also be noted that not all leaks do break to the surface (or take a very long time to do so) and hence reactive leakage often leaves a number of leaks running for a very long time.

Locate

Once the area in which a leak occurs is identified then its exact location needs to be determined. The most common way of doing this is to listen for the sound that the leak makes. This has been done by the human ear for decades, normally using a listening stick (or recently using an electronic equivalent), to assist with listening to the sounds from the network. The sound of the escaping water can be identified and pinpointed by a trained technician allowing the location of the leak to be found.

In the 1980s this was supplemented with correlators that used the speed of sound in the pipe wall and water column, to determine the location of a leak between two measurement points. This improved the pinpointing of the leak but requires accurate pipe material information to be fully effective.

These acoustic methods have been supplemented by additional methods, many of which were in the original "National Water Council Standing Technical Committee Report No. 26"1:

- Isolating small areas of the DMA to see the impact on the flow (step testing)
- injecting inert gas that can be identified when it escapes the pipe
- in-pipe inspection techniques
- acoustic loggers either permanently installed on the network, or moved to different locations on a regular basis. A number of companies are installing significant numbers of these in AMP7

Recently remote analysis using either satellites, drones or fixed wing aircraft have been used to look for areas where water has escaped the main. These are effective on large rural pipes that would take a long time to survey by foot.

Hydraulic models and enhanced data analysis, have also started to be used to locate the locations of leaks by using mathematical models to identify the most likely leak location based on the data available.

Mend

Fixing leaks is normally carried out through digging a hole and either a clamp being applied to the leak, or a small section of main is cut out and replaced. Mending the pipes accounts for approximately 80% of the total cost of the "find and fix" process. Currently around three quarters of small diameter pipes repairs are made using a repair clamp.

To date there has been limited research and development in improvements in repair techniques in the UK, however technology is starting to emerge that some companies are making use of to reduce the footprint of repairs. The relatively dense population of the UK and crowding of underground utility networks can typically make some small footprint techniques less effective when applied in the UK, and this is an area requiring further research, development and innovation.

There are also added complications in recent times of council lane charging systems that can cause delays in repairs and significant costs. Both of these consequences impact leakage, meaning a leak may run for longer than necessary or the cost of repair may be greater.

3.4 Context of the AMP7 targets

In England, Wales and Scotland leakage targets have been previously set based on the concept of an economic level of leakage (ELL). Essentially, the costs of controlling leakage are balanced against the savings incurred from reducing the volume of water leaking from the network.

Typically, the costs of leakage control include: finding and repairing leaks, reducing water pressure and replacing water pipes. The costs potentially saved by reducing leakage can be expressed as: short-run costs (the costs of treating and pumping water from existing water treatment infrastructure), or long-run costs (the costs of developing increased capacities in water supply).

Economic levels of leakage are derived by each company and audited by the regulators. In 2009, the methodology was improved to include social, environmental and carbon costs in the assessment of costs of leakage control and water lost, which became known as the sustainable ELL or SELL. The SELL can be based on either a short-run methodology, focused upon the costs of managing leakage and the cost of water lost, or long-run where leakage reduction is considered against the cost of new water supply options as part of the wider management of supply-demand balances in water resources planning. Targets have been based on the SELL principles up to 2020, with most companies being at or below the short-run SELL, some being driven to go further due to local supply-demand balance challenges and needs.

There have been various studies to investigate alternate target setting approaches, including:

- The inclusion of abstraction taxes, or abstraction incentive charging
- Trading in leakage permits
- Targets set on water into supply or on abstraction level
- A corporate social responsibility approach
- A frontier efficiency approach

In 2018 the National Infrastructure Commission's report on 'Preparing for a drier future' concluded that leakage affects customer attitudes towards reducing their own consumption and makes supplies less reliable and recommended a long-term target to reduce leakage by 50% by 2050.

At the same time, Ofwat consulted with companies on the concept of reducing leakage by at least 15% in AMP7 (2020-21 to 2024-25). This resulted in each company in England and Wales being set a performance commitment to reduce leakage by the percentages shown in Table 2 in AMP7.

Table 2 – Leakage reduction commitments set out at PR19 for all English Water Companies

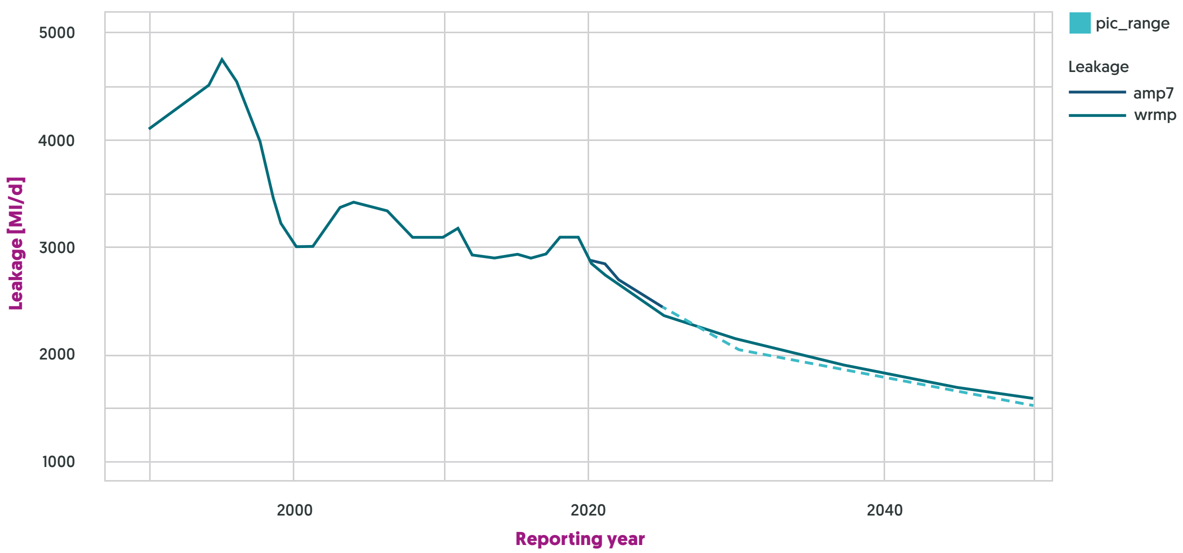
Water and Sewage companies	Leakage reduction targets for 2024-25
Anglian	16.4%
Northumbrian North	11.0%
Northumbrian Essex & Suffolk	18.5%
Severn Trent	15.0%
South West	15.0%
Southern	15.0%
Thames	20.4%
United Utilities	15.0%
Wessex	15.0%
Yorkshire	15.0%
Water only companies	**Leakage reduction targets for 2024-25**
Affinity	20.0%
Bristol	21.2%
Portsmouth	15.0%
SES Water	15.0%
South East	15.0%
South Staffs	15.0%
South Staffs Cambridge	13.8%

3.5 Water Resources Management Plans forecasts to 2050

The Water Resources Management Plans submitted to the Environment Agency[17], show water companies' long-term analysis of their leakage reduction requirements.

Figure 3.10 shows the size of reduction that was identified compared to the PIC. Only 4 companies produced WRMPs based the 25 year horizon, the other companies were extrapolated by continuing their leakage reductions between 2040 – 2045.

Figure 3.10 – Water resources management plan 2019 forecasts of leakage to 2050



As can be seen in Figure 3.10, the current forecast suggests the reductions required by 2030 would not be quite achieved. Only four companies produced WRMPs based on the 25-year horizon; the other companies' forecasts have been extrapolated from current leakage reduction trends.

[17] EA. Revised Draft Water Resources Management Plan 2019 Supply-Demand Data at Company Level 2020/21 to 2044/45, August 2019 www.data.gov.uk/dataset/fb38a40c-ebc1-4e6e-912c-bb47a76f6149/revised-draft-water-resources-management-plan-2019-supply-demand-data-at-company-level-2020-21-to-2044-45

3.6 Performance in Year 1 of AMP7

2020-21 was a challenging year for water companies' leakage performance. This was the first year that represented a glide path containing significant reductions for many companies, compared to a decade of maintaining levels at the SELL or making gradual reductions for most companies.

Leakage is an estimation and the first year of reporting under a new methodology, coupled with significant changes in customer behaviour due to the Covid-19 pandemic, had considerable bearing on water accounting and changes in water use. These factors also brought challenges in dealing with the management and resolution of customers' leakage issues.

A significant cold spell created a freeze-thaw event, and the combination of factors has been challenging for the industry given several factors coinciding at the beginning of AMP7. This led to four companies failing to meet their Year 1 AMP7 commitments but overall leakage in the England reduced from 2019-20 to 2020-21 by 37Mld.

SECTION 04

Defining the Pathways

4.1 Interventions to reduce leakage

In order to construct the potential pathways to achieve the PIC and NIC targets for leakage there are a number of interventions that can be used to reduce leakage.

These interventions impact the mechanisms of leakage in different ways and have impacts on the performance of other interventions in a positive or negative manner.

As part of the initial phases of the route map construction two workshops were held, bringing together leakage practitioners from the water companies as well as leading consultants in the leakage arena. The interventions presented below have taken the outputs of the workshops which identified 83 separate actions that could be used to reduce leakage in the UK. These have been grouped into eight intervention groups based on actions that had similar impacts on leakage on specific asset groups in the network. These interventions are capable of achieving the PIC however in the interests of ensuring leakage reduction is affordable, innovation is required (see separate Innovation Annex for more detail):

- Improved ALC
- Optimum pressure managed networks
- Improved repair techniques
- Smart metering and advanced data analytics
- Smart networks, new sensors with advanced analytics
- Progressive pipe rehabilitation
- Adoption of customer supply pipes
- Supply pipe replacement.

There are also interventions on service reservoirs and the trunk main network. The trunk main network will react in a similar way to smaller pipes in the distribution network to many of these interventions and for the purpose of this study has been included as part of the wider network. Service reservoirs are a special case of leakage and need to be monitored in a robust manner to ensure that leakage does not occur in these structures. For the purpose of this study, we have assumed that service reservoir leakage is negligible when compared to network leakage and so has not formed part of our modelling.

4.1.1 Method for determining leakage benefits of interventions

To allow the benefits of leakage to be modelled a number of factors that impact leakage levels were identified. These factors all combine to give the overall leakage level for an area. These factors are then altered in different ways by the interventions, and hence the impact of an intervention can be determined.

The factors that impact the leakage levels are:

- **Leak breakout rate** – this is the rate at which leaks form on the network. It is sensitive to the pressure of the network as well as its age and quality.
- **Number of leaks** – this is the number of leaks currently on the network. It is impacted by most of the interventions, as many of the interventions are focused on reducing the number of leaks that are running at any one time.
- **Leak flow rate** – this is the size of the leaks and how much water is escaping. It is changed by the pressure in the pipes, but also at the speed of detection as leaks will grow over time.
- **Leak awareness time/ location time** – this is how long the leak takes to locate, and for a repair job to be raised. This is heavily associated with the amount of active leakage control there is, but also how efficient and effective these activities are at finding the leak. It is also impacted by the number of sensors and their use across the network.
- **Leak repair time** – this is how long the leak takes to repair once located. It is impacted by the quality of the detection activity (if the location of the leak is poor then this will cause a dry hole or a resurvey) as well as how the repair is done. As customers are often responsible for the repairs on their supply pipe this can also lead to a long repair time.
- **Background leakage** – this is the level where leakage cannot be reduced further, using current detection technology. This can be altered by replacing pipes in the network, but also by reducing pressure in the network. It can also change due to new technological innovations that make detection more effective.

Table 3 shows how each of the factors impact the interventions. The factors have all been constructed so that a positive impact from an intervention will cause a reduction in one or more factors. The way in which the factors are impact by each intervention will differ depending on how that intervention has been implemented.

There is also a significant amount of uncertainty that is associated with these leakage interventions and this has been taken into account. These uncertainties are often asymmetrical. As suggested, some of the activities suggested would result in a more certain future and hence the uncertainty being reduced.

Table 3 – Impact of interventions on leakage factors

Intervention	Leak breakout rate	No. leaks	Leak flow rate	Leak awareness/ location time	Leak repair time	Back-ground leakage
Improved ALC	0	↓	↓	↓	↓	0
Optimum pressure managed networks	↓	0	↓	0	0	↓
Improved repair techniques	0	↓	0	0	↓	↓
Smart metering and advanced data analytics	0	↓	0	↓	0	↓
Smart networks, new sensors with advanced analytics	0	↓	↓	↓	↓	0
Progressive pipes rehabilitation	↓	↓	0	0	0	↓
Adoption of customer supply pipes	↓	↓	↓	0	0	↓
Supply pipe replacement	↓	↓	↓	0	0	↓

4.1.2 Methodology for estimating cost of interventions

Leakage costs are modelled for steady state conditions (countering the impact from leak breakout and growth) and for reducing leakage each year. The leakage profiles from 2021 through to 2050 are defined by four scenarios and their associated interventions. The assumptions made in the modelling are outlined in Appendix 1.

The steady state costs are modelled using Method A principles that originate from the Tripartite economic level of leakage report[18]. This relies on estimating the total number of leaks that break out each year and the cost of finding (active leakage control costs) and repairing those leaks. The active leakage control costs are sensitive to the background level of leakage, and the costs rise exponentially as leakage approaches the background level. We therefore expect that the steady state costs increase from year to year as the level of leakage reduces.

Leakage reduction interventions are modelled using the Method A model alongside other intervention models based on the costs and benefits of options such as asset renewal, pressure management and smart networks. The cost of reducing leakage using active leakage control is modelled by estimating the number of additional leaks that need to be found and fixed each year to lower leakage, again using the Method A approach.

This can only be done where the leakage level is above a value determined by the background leakage and the amount of leakage reported by people spotting leaks and bursts.

The active leakage control and repair costs and leakage reduction from each of the interventions used in the scenarios (Table 3) are modelled by varying one or more of the following:

- Leak breakout rate
- Number of leaks
- Leak flow rate
- Leak awareness time
- Leak location time
- Leak repair time
- Background leakage.

Capital costs and other costs for specific interventions are also modelled using a range of data and assumptions. These include optimising the pressure in the network, smart metering, smart networks, distribution network replacement and improvement (this last category uses data derived from TR61[19] outputs to generate weighted average unit costs based on different techniques and ground conditions).

Costs are then assembled for each of the scenarios over the period 2021 to 2050. The net present value (NPV) of the costs for scenarios 2, 3 and 4 are then compared to the NPV of the costs for scenario 1.

[18] Tripartite Group, Best practice principles in the economic level of leakage calculation, March 2002
[19] WRc, TR61, www.wrcplc.co.uk/asset-resilience

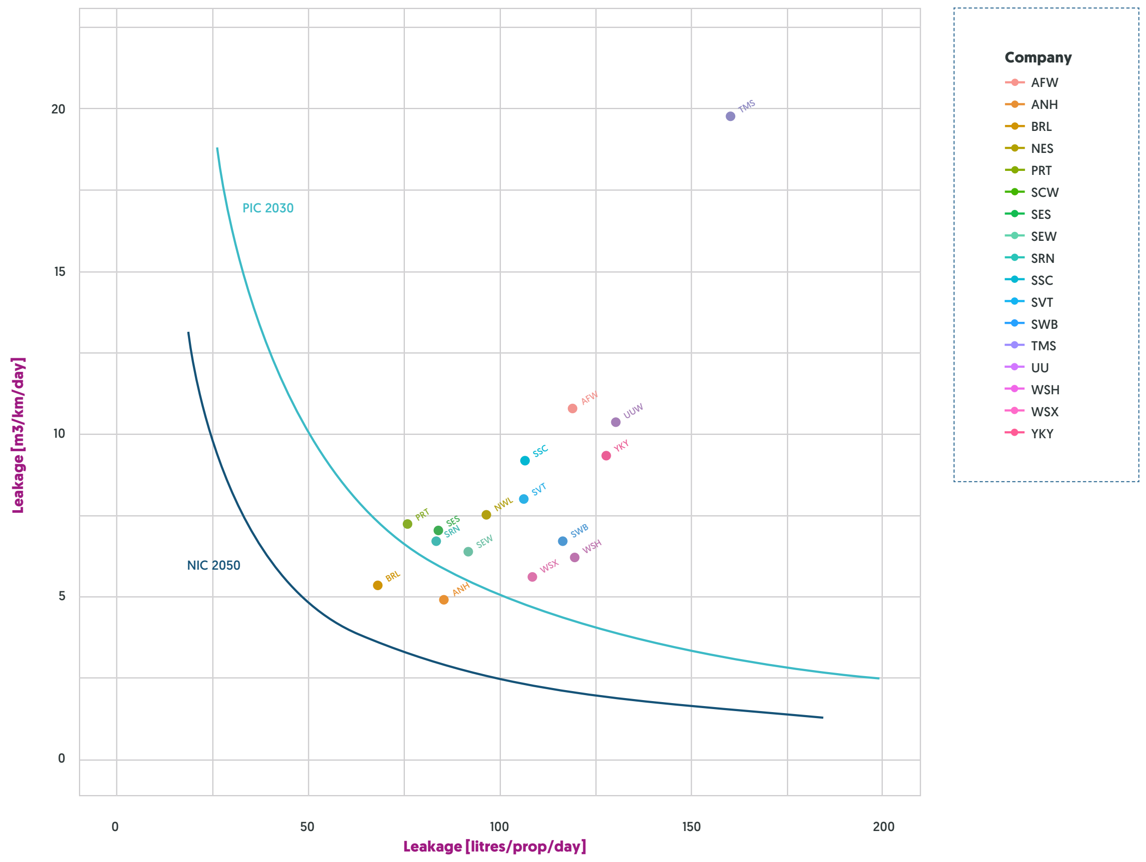
4.2 The need for adaptive pathways

There are a number of options that can be chosen to reduce leakage, however there are a number of potential constraints, risks and opportunities associated with each of these. Coupled with potential future changes, this could result in a tipping point being reached at which further progress may not be possible or costs may become prohibitively expensive.

High-level cost and benefit modelling highlights that there is not currently a single clear route to achieving the PIC or reducing leakage by 50% from current levels by 2050. This is due to some of the uncertainties in relation to variables such as the level of background leakage, and in relation to how technology and innovation may result in a step- change for some of the individual interventions.

The challenges will differ for each water company as well. Not only are the networks different, but the relative starting positions are also different. Figure 4.1 shows the current leakage positions of the English and Welsh water companies. The two boxes in the lower left corner are the approximate targets needed to achieve the PIC and the NIC, assuming that network density remains approximately constant. As can be seen currently Bristol Water are the only company that have a leakage level low enough to meet the PIC. This means that all companies need to perform the same as Bristol by the end of 2030. Figure 4.1 also shows that no company currently has a level of leakage needed to achieve the NIC target of 50% reduction.

Figure 4.1 – Current leakage performance against PIC and NIC targets



Taking these factors into account, below are a number of potential alternative versions of the future and how these may impact upon the interventions positively, or negatively. The tables below indicate green where there is a positive change and red indicates a negative change.

Future version A

This future looks at significant innovation and lower background leakage levels, Figure 4.2, shows the balance between operational and capital solutions in this potential future. Table 4 shows the potential impact on the interventions if find and fix costs are lower due to innovative solutions.

Figure 4.2 – The balance between operational and capital solutions for a future with significant innovation and lower background leakage levels

Table 4 – The impact of innovation reducing find and fix cost on leakage other interventions

Intervention	Cost	Benefit
Improved ALC	↓	↑
Optimum pressure managed networks		
Improved repair techniques	↓	↑
Smart metering and advanced data analytics		
Smart networks, new sensors with advanced analytics	↓	↑
Progressive pipe rehabilitation	↑	↓
Adoption of customer supply pipes		
Supply pipe replacement		

Whilst some potential improvements in efficiency "naturally" are possible, the activity of carrying out active leakage control in the UK is a relatively mature one, and in order to achieve significant improvements, enablers are required to drive a step-change in performance.

The interventions could be improved via a number of different approaches and the specific approach used will vary from company to company depending on their asset condition and performance, leakage level, background level of leakage, DMA characteristics and level of maturity in a certain approach. For example a company that is already developing a smart networks strategy is likely to prefer to continue with that approach. Table 5 summarises how different approaches could change the economics of managing leakage, and is not to be considered an exhaustive list but to illustrate the types of enablers that could result in positive change over time:

Table 5 – Enablers to change find and fix leakage economics in the innovation future

Enabler	Examples	Benefit	Risks
Traditional	Sub metering of DMAs	Improves efficiency of active leakage control, proven approach as based on the principles of DMAs.	Relatively slow to implement and benefit can take several years to realise. Underlying network and customer side deterioration (not necessarily bursts) may apply upwards pressure to leakage. Long-term decision as asset life of chambers circa 40 years.
Smart networks and advanced analytics	Network sensors coupled with advanced analytics and AI covering worst performing parts of networks.	Significant reduction in leakage due to reduced awareness time and reduced ALC costs as leaks are located more quickly. Low risk no-regrets type decision as asset life is relatively short e.g. less than 10 years. Solution may be scalable and able to be redeployed.	Benefits across the industry are somewhat unclear, but data will improve as greater rollout expected in AMP7 delivery.
Improved repair techniques	The development of innovative repair techniques e.g. in-pipe or keyhole type repairs.	Reduction in the overall cost of reducing leakage through cheaper and potentially quicker repairs. Transitional costs may be less of a barrier to reducing leakage through find and fix. Reduced time to repair may also result in H&S benefits and reduced traffic management impact, along with reduced social cost impact.	Likely to take several years to develop and requires extensive testing to prove effectiveness. If the techniques do not develop in time, may result in a tipping point where find and fix becomes too expensive. Councils may increase costs of traffic management in the shorter term.
Remote Sensing	Remote sensing using drones and/ or satellite imagery	Potential use of vegetation indexing, ground movement or chlorine detection to identify leakage.	Relatively new technique and cost-benefits need to be fully assessed under a variety of different seasonal conditions and spatial variation could impact on benefit. Underlying network and customer side deterioration (not necessarily bursts) may apply upwards pressure to leakage.

Figure 4.3 – The balance between operational and capital solutions for a future with an asset management focus

Table 6 – The impact of improvements in asset management on leakage interventions

Intervention	Cost	Benefit
Improved ALC	↑	↓
Optimum pressure managed networks		
Improved repair techniques	↑	↓
Smart metering and advanced data analytics		
Smart networks, new sensors with advanced analytics	↑	↓
Progressive pipe rehabilitation	↓	↑
Adoption of customer supply pipes	↓	↑
Supply pipe replacement	↓	↑

In this hypothetical example, if the level of background leakage is similar to or slightly higher than currently estimated, it may prove increasingly challenging and expensive to reduce leakage through the reduction of awareness time of existing leaks. If smart networks solutions prove to be relatively expensive and economies of scale do not materialise, whilst at the same time if background leakage can be effectively targeted for asset renewal and if leak free new networks become achievable with relatively minor improvements through technology or improved quality of installation, an asset focused approach may be preferable in the longer-term. Improvements in data on condition as well as advanced analytics might combine to develop a better value approach for asset rehabilitation, with lasting benefits and wider benefits than just leakage reudction [Table 7].

Table 7 – Enablers to change leakage economics in the asset management future

Enabler	Examples	Benefit	Risks
Adoption of customer supply pipes	Adoption of customer supply pipes enabling proactive asset management of customer side leakage.	Ability to proactively intervene rather than reacting to leakage on customer side.	Customer side leakage is a key risk and a "known unknown" due to limited data availability. May take significant time to influence performance even with a proactive approach.
Improved ability to lay leak-free new networks	Improved understanding of leakage on new networks in relation to soil type, materials, joints, quality control, processes etc.	There may be potential to improve the current processes to result in leak-free new networks without requiring new technology. May result in a more sustainable reduction in leakage in the longer-term.	Being able to target leakage and not just bursts is a requirement. Likely to take considerable time to influence leakage levels.
Better targeting of leakage (not just bursts)	Improved processes to target leakage and not just the pipes bursts e.g. background leakage, communication pipes.	This may make achieving leakage reduction sustainable in the long-term.	There may not be a viable way of targeting background leakage, resulting in whole DMA/whole cohort within a DMA policy being required which may be expensive.
Improved data on condition and performance	Improved data on condition and utilising tools such as AI and advanced data analytics to improve the link with performance.	This may enable asset rehabilitation to be made based on better decisions using both models and physical datasets combined to deliver the best-value schemes.	May be impossible to identify background leakage.
Improved materials and/or jointing	Technology may develop to improve joints on PE pipe.	This potentially could remove the human element of the process, confirming all joints are installed to a high standard.	The development of new technology may not happen if there isn't perceived to be a market driver in the UK water sector.
Improved relining options	Improved structural and non-structural relining techniques		Short term behaviour can be driven by supply interruptions metrics than can dissuade asset management options.

4.3 Scenarios

To identify and test potential routes for the sector to reach the PIC by 2030 and the NIC commitment by 2050, four potential scenarios through the adaptive pathway have been considered.

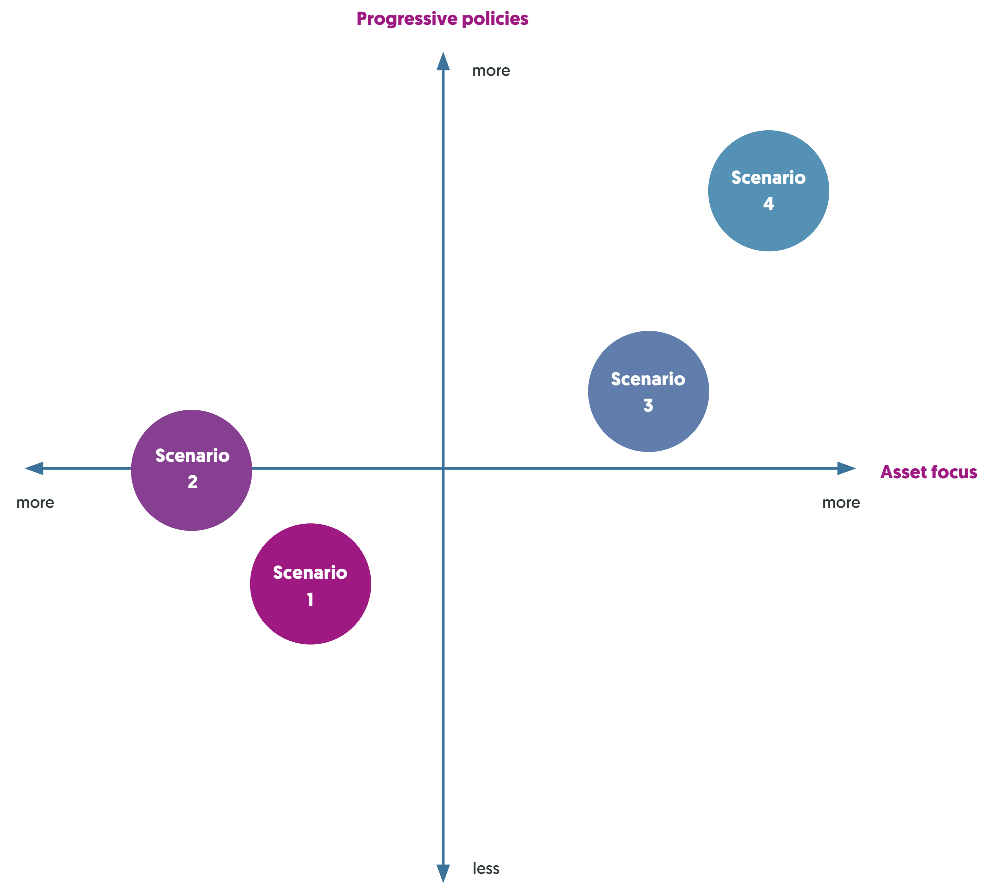
Each of these scenarios reflects an alternative future with its own focus on specific interventions. As the starting situation of all companies is varied with respect to their current performance, existing commitments and distance from the current assessment of background leakage, the scenarios illustrate how companies might meet their leakage targets. Each scenario also examines the additional benefits to other outcome delivery incentives as well as the cost of water saved by reducing leakage.

To achieve the leakage targets set out in the scenarios there will need to be a concerted effort from all parts of the sector. Water companies, the supply chain, government and regulators will all need to work together to achieve these goals. This will come in the form of collaborating on innovation, providing appropriate regulation and legislation. Some of the scenarios highlight that, due to the uncertainty around things like background leakage, the possibility of achieving the PIC and NIC targets is remote.

It has been assumed in all scenarios that the AMP7 ODI commitments will be delivered, as these are regulatory commitments and already funded in the previous price review. The methods used to achieve the commitments have been varied to reflect the changes that would be needed based on the scenarios. The scenarios vary in how and the quantity of the interventions described above are implemented. They also reflect the different decisions that would need to be taken and when these decisions would be needed to allow delivery of the benefits.

The main focuses of the scenarios are presented in Figure 4.4. This helps visualise the differences between the factors that drive the scenarios as well as how they differ in their principles.

Figure 4.4 – The main drivers and focuses of the four scenarios



4.3.1 Limited low-hanging fruit (S01)

This scenario is based around doing significantly more active leakage control, without any additional investment in asset renewals or customer metering above what has already been proposed in the PR19 business plan. This scenario also assumes that during AMP7 there is limited further work to understand and quantify the risks associated with leakage reduction such as the size of background leakage and the amount of leakage that occurs on the customer supply pipe.

In this scenario reaching the AMP7 targets has exhausted all the low-hanging fruit to reduce leakage, and there have been limited technological advances. It has been assumed that there are limited roll-outs of smart networks and the analytics surrounding them to produce insight.

4.3.2 Smarter networks (S02)

This scenario is based around the development of AMP7 policies and activities that are currently used to achieve the ODI target and extending the use of smarter networks through AMP 8. Smarter technology and process efficiencies are developed with the supply chain and adopted by all companies; these include better ways to repair leaks as well as use of smart technology to maximise leakage reductions.

Increased investment in leakage allows for the gains made in AMP7 to be continued in AMP8 and beyond, with further technological advances providing additional efficiencies in later years. There is an assumption that the asset renewal rates continue at a similar rate to the AMP7 rates and are mainly focused on reducing bursts rather than for leakage purposes. This closely relates to Ofwats low technology scenario8.

4.3.3 Data and asset focused improvements (S03)

This scenario is based on a data-driven approach, where improvements in understanding and insight drive leakage reductions. It assumes that all of the risks and uncertainties already identified are fully understood and quantified before the submission of WRMPs. This is turn drives policy changes from water companies leading to additional investment in pipes renewals, smarter technologies and associated analytics.

This scenario also assumes that there is a strengthening of the cross-company sharing around technology and process insight, so that all companies can learn from the trials done by others. This "what works well" insight will help to drive collaborative innovation that is supported by the supply chain, providing further leakage reductions towards 2050. This closely relates to Ofwat's high technology scenario8.

4.3.4 Progressive policies drive asset focus (S04)

This scenario is based on a different regulatory framework that is strongly focused on the long-term sustainable reduction of leakage. The framework allows for a different approach to customer-side leakage either through adoption or some other mechanism that ensures leakage on customer supply pipes is reduced. The need for sustainable solutions drives a large amount of asset replacement (which includes supply pipes if adopted), which in turn drives innovation and efficiencies from the supply chain in this area.

There is also the assumption that this new framework also allows for small course corrections to be applied by way of continuous evaluation against the adaptive pathways. This is so that the most cost-effective route can always be selected to achieve the long-term goal.

4.4 Limited low hanging fruit

The limited low hanging fruit scenario has active leakage control focus without any additional technological insight or process improvements. Its main focus is to outline the costs and challenges of using pre-AMP6 style interventions to achieve the targets.

This scenario is also been constrained by background leakage which means that the reductions required by 2050 are significantly below the background leakage levels as they are currently understood. This leads to a significant uncertainty that this approach will achieve the NIC or PIC targets.

The interventions which contribute the most to this scenario are:

- **Improved active leakage control** – significantly greater amounts of active leakage control would be needed, greater than what is currently done.Some efficiency would be gained by increasing the amount of this activity, but this would be capped due to the increasing difficulty to find leaks as background leakage is approached. Further inefficiencies may be seen as active leakage control resource is increased as there are only a finite number of DMAs to do leakage detection in, meaning each technician would have less leakage to find.
- **Optimum pressure-managed networks** – the pressure in the network will be reduced and better managed. New pressure-reducing valves will be installed, as well as all existing pressure management schemes being fully optimised. A culture of calm networks is also adopted so that fewer issues are caused by operations on the network that lead to leaks.

4.4.1 Key areas of uncertainty

Many of the uncertainties exist in all of the scenarios. In the development of the limited low hanging fruit scenario the main uncertainties considered were:

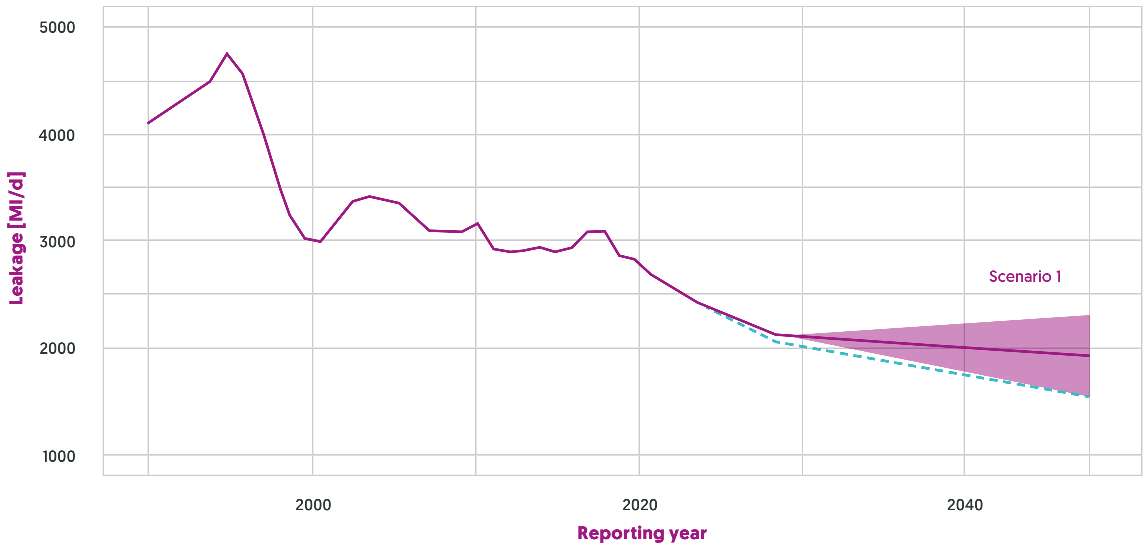
- **Background leakage** – as there are limited interventions in this scenario that reduce background leakage, the sensitivity of the starting value will be significant. If the background leakage of the network is lower than anticipated then there will be a potential to achieve the targets in a cost-effective manner, however if the background levels are higher than anticipated then the cost to achieve the target would be very high.
- **Future costs** – the future costs of active leakage control resource is a significant uncertainty. There is scope for prices to go both up and down by the end of 2050. This may close off, due to the cost of resource (or make very expensive), this scenario, which would mean that another route through the adaptive pathway would need to be taken.
- **Customer supply pipe leakage** – as little is done to estimate customer supply pipe leakage in this scenario, there is uncertainty about how much of total leakage occurs on pipes not owned by the water companies. There will also be limited information on which supplies are leaking as customer metering is limited.

4.4.2 Benefits

Leakage

This scenario has limited benefits as it relates to achieving the PIC and NIC targets as shown in Figure 4.5. If background leakage is significantly lower than current estimates there is a possibility that this scenario would lead to the reductions as laid out in the NIC, however the speed of these reductions is likely to mean that the PIC target is not achieved until 2050. The initial speed of reduction is reduced over time as increases in asset deterioration outweigh efficiencies gained.

Figure 4.5 – Leakage reductions to 2050 for the limited low hanging fruit scenario



Overall system

Due to the limited amount of asset renewal and capital expenditure that will occur during this scenario, there are limited benefits to other areas of the overall system by following this approach. Research has shown that by having a calmer network you reduce the number of failures that will occur. This in turn will reduce the potential for interruptions to supply as well as flows that could cause water quality issues.

4.4.3 Risks and opportunities

A SWOT analysis was performed by the water company leakage practitioners, members of regulation teams and the authors. The outputs are summarised in Table 8.

Table 8 – Limited low hanging fruit SWOT analysis

SWOT	Scenario 1 - Limited low hanging fruit
Strength	**Familiarity** – This approach to leakage has been used for several years and the leakage community understand how to implement the scenario. This will also help with inclusion in future business plans as there are fewer assumptions on performance. **Benchmarking** – As this approach has been done for some time there is a significant amount of data, as well as some understanding of frontier performance. **Not reliant on asset renewal** – As a more Opex-focused scenario there is limited reliance on asset renewals to produce leakage benefits. These renewals would cause disruption and have a higher embeded carbon impact, as well as having significant upfront cost.
Weakness	**Background leakage** – An accurate estimate of the current background leakage position is not known. If it is higher than anticipated, then the costs associated with achieving the targets will be much higher than anticipated. This also means that the risk of this scenario not achieving the reductions required is very high. **Deteriorating asset base** – With limited asset renewal there is a potential that the network assets will begin to deteriorate at a significant rate, increasing the natural rate of rise. This increase would make achieving the target even more difficult. **Resource management** – With significantly more people to manage, there maybe challenges around the management of these technicians. This could lead to inefficiencies in performance that would have to be overcome. **Possibility for further pressure reductions** – Pressure reduction has been used extensively across the water network for several decades. It is unclear whether the amount of leakage reduction needed through pressure management is viable given the current customer level of service commitments. **Limited additional benefit** – Due to the nature of the scenario there is limited improvement to the overall water delivery system. Having a purely leakage-focused solution may cause under-investment in other areas that would need to be addressed in the future.
Opportunity	**Optimisation of existing technology** – By optimising the current technology, the industry would not need to spend time on new unproven technology and hence have a greater focus on delivery of the ultimate goal. **Cheaper solution** – Potentially (if background is significantly lower than anticipated) this could be a lower cost than any of the Capex-heavy scenarios. However, the risk of failure is also very high, if this was to occur then the industry could potentially be accused underspending.
Threat	**Reputation** – As the achievement of the PIC is highlighted as being a step change in performance, delivering it a similar way to historical targets may not be viewed well, and invite questions about why this level of performance was not achieved earlier. **Resources** – The industry has already seen a lack of active leakage control resources during Year 1 of AMP7, with several vacancies both in water companies and the supply chain. It will be difficult to hire sufficient resources to meet the needs of this scenario.

4.4.4 Consideration of company characteristics

Some companies in the lower left corner of the metric charts (Figure 3.5), may be much nearer to their background leakage than those further to the right. As such the cost associated with achieving leakage for these companies could be higher and mean that this route through the adaptive pathway will not deliver the required benefits.

Smaller companies may find it more difficult to recruit the level of resources that are needed to achieve the targets in this scenario. This is assumed due to their smaller footprint and locality to the job being an important factor. They may need to pay higher prices to attract resources from outside their geographical footprint. Companies with higher cost of living may also find that they need to pay more, due to salaries being generally higher in these areas.

Companies with the older networks, may have higher natural rate of rise than those with the younger networks. This would mean more leaks are likely to break out and hence there is already a harder job to achieve steady state leakage targets, and therefore in achieving reductions.

However, it is worth noting that those companies with a higher percentage of plastic pipes will potentially find active leakage control less efficient as the normal acoustic methods used are not as effective on plastic pipes.

4.5 Smarter networks

This scenario is based on the continuation of the AMP7 business plans and water resources management plans through to 2030 and 2050 with organic innovation leading to some improvements. The focus of this scenario is to show how successful the industry can be by continuing on with the current plans and assumptions, with efficiencies being achieved by improved smarter networks and sharing of some data between companies.

The origins of this scenario mean that it has been based around the supply and demand balance for each company and so there are some significant differences in approach specifically between companies in the water stretched south east and those in the north of the country. Also, companies in AMP7 have already focused on different strategies to achieve the targets, with smart networks, acoustic logger deployment and pressure management all being employed to achieve the AMP7 targets.

The interventions which contribute the most to this scenario are:

- **Improved repair techniques** – water companies have already come together to investigate how repairs could be made more efficient through group projects and UKWIR. It is assumed that these projects provide meaningful results that assist with cost-effective repair techniques that reduce distribution, but also are sustainable.
- **Smart metering and advanced data analytics** – some water companies are already installing Advanced Metering Infrastructure and Automatic Meter Reading solutions. It is assumed that they continue with this rollout, but also improve in the analysis of this data, which assists with finding leaks during periods of high or erratic consumption as well as on customer supply pipes.
- **Smart networks, new sensors with advanced analytics** – a large number of acoustic, flow and pressure sensors have been installed during the end of AMP6 and AMP7, and it is assumed that this type of strategy will be rolled out to a wider number of areas as well as being adopted by other water companies. The analytics around these data sets will build on the data already available, with machine learning and A.I. being further used to improve the active leakage control. With more data the volume being lost through a specific leak is better understood allowing better prioritisation of leak repairs.
- **Improved active leakage control** – active leakage control will continue to be used to confirm leak locations and contribute to activities around the smart network's initiatives. The large amount of insight that is gathered from the smart networks means that the active leakage control technicians can be more effective. Detection technology continues to be developed assisting with these activities.

4.5.1 Key areas of uncertainty

Many of the uncertainties exist in all the scenarios. In the development of the Smarter networks scenario the main uncertainties considered were:

- **Cost of technology** – technology costs have the potential to rise (as has been seen in 2021 with a global shortage of microprocessor chips), but they can also reduce if market pressures, and efficiencies are exploited. This will make a significant difference to the overall cost of this scenario.
- **Number of sensors required** – there is not yet consensus in the industry of the number of sensors needed in a district meter area to be effective. This will have an impact on the costs and the effectiveness of the leakage activities in this scenario.
- **Leakage savings from smart networks** – although several companies have trialled smart networks, the full benefits to leakage are not fully understood. If the techniques are more effective than seen in the trials, then there could be additional leakage savings (or reduction in cost). Similarly, if the techniques are less effective, then they could cause costs to rise.
- **Smart network asset life** – the trials of the smart networks are still relatively new, hence the true asset life of the sensors and associated assets are not yet fully known. If these are shorter than anticipated then the sensors will need to be replaced (or maintained) more often, which would obviously increase the costs of this scenario. If the opposite is true and asset life is longer then this could significantly reduce the cost of this scenario.
- **Background leakage** – this scenario is very sensitive to background leakage. A 10% movement from the initial estimate of background leakage, would significantly change the deliverability of this scenario.

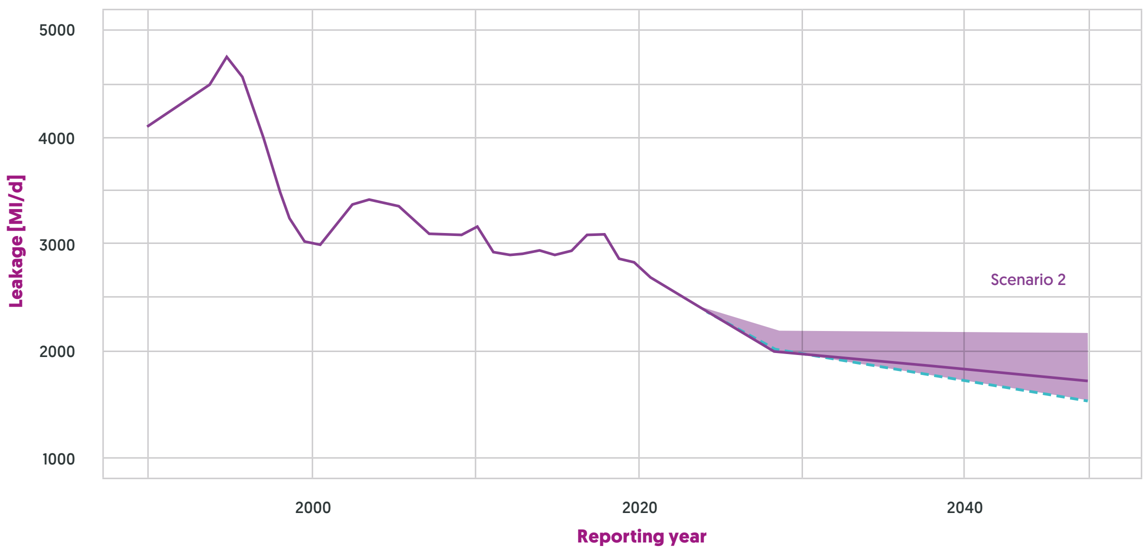
4.5.2 Benefits

Leakage

Following this scenario, the PIC target in 2030 is likely to be achieved with the AMP7 reductions continuing at a similar rate into AMP8 as shown in Figure 4.6. However due to the limited asset renewal that is associated with the scenario the deeper reductions needed to achieve the NIC target will not be achieved by 2050 as the rate of reduction is slowed.

The leakage reductions in AMP7 are continued into AMP8 and the PIC is achieved by 2030 as shown in Figure 4.6.

Figure 4.6 – Leakage reductions to 2050 for the smarter networks scenario



Overall system

The increased number of sensors will assist with interruption to supply metrics, as water companies will be aware of incidents sooner, and be able to pinpoint issues more effectively with the data that is being generated.

More customer meters will provide better insight into consumption patterns. This information will be useful in achieving the proposed per capita consumption targets, through better understanding of behaviour. This understanding will allow for better targeting of water efficiency work.

Improving the repair techniques has the potential of assisting with the general asset management of the network. New techniques may not fix pipes but could strengthen weak spots to improve the network's overall performance.

4.5.3 Risks and opportunities

A SWOT analysis was performed by the water company leakage practitioners, members of regulation teams and the authors. The outputs are summarised in Table 9.

Table 9 – Smarter networks SWOT analysis

SWOT	Scenario 2 - Smarter networks
Strength	**Technology** – With a stronger focus on technology in this scenario, there can be an optimisation of the technology that has provided benefits. Also technologies that have not provided benefits can be stopped to save expenditure. **Cost curves** – Companies that are at the frontier of leakage performance will have cost curves that can be used by the whole industry to assist with future analysis. **Universal metering** – Some companies will be approaching universal metering by the end of AMP7, with more being close to this mark by the end of AMP8. This will significantly assist with the quantification and understanding of the prevalence of customer supply pipe leakage.
Weakness	**Metering** – Without 100% metering there will still be some issues in identifying customer supply pipe leakage in an effective and efficient manner. **Focus of find and fix** – With the continued focus on find and fix activities, there will be limited focus on fundamental reasons why there are high leakage levels. **Upper quartile performance** – With the regulatory drive for all companies to achieve upper quartile performance and hence a competition element, there is less incentive to share data and insight, as you would lose your competitive advantage.
Opportunity	**Increased knowledge share** – Ensuring that trials of new technology are done in a uniform way, the learnings from the trials can be used by multiple water companies, without the need to repeat the trials. This would save costs as well as helping to break down innovation barriers that could prevent innovators from assisting the industry.
Threat	**Efficiencies are not sufficient** – At lower levels of leakage the efficiencies provided by the smart networks may not be sufficient to outpace the increase in the natural rate of rise. This would lead to a more active leakage control activities being required, which would push this scenario towards the scenario 1 path. **Communication issues** – With a heavy reliance on communications from the smart network, this scenario is open to a Carrington Event (a large geomagnetic solar storm that significantly impacts electrical communications and causes electrical blackouts) type of disruption, which could knock out communications. There is a low likelihood this would happen, but the potential impact would be significant and it would take a long time for the network to recover.

4.5.4 Consideration of company characteristics

Several companies have already begun to install smart networks and could provide insights to companies that have not yet done this.

Companies that already have a high meter penetration will have some information on consumption of their customers.They will also be able to retrofit existing meters with more advanced technology at a cheaper unit rate than were they to install completely new meters, meaning they could gain insights from their customers' water consumption.

4.6 Data and asset-focused improvements

This scenario is based on collecting and exploiting more data from the network, this is combined with asset renewal at rates above those currently seen helps to reduce all aspects of leakage. The focus of this scenario is how data and advanced analytics can be used to assist leakage activities.

It highlights some of the challenges of only tackling leakage in a proactive manner on the network and not having a concerted effort to reduce leakage on the customer supply pipe side of the network.

The interventions which contribute the most to this scenario are:

- **Smart metering and advanced data analytics –** universal smart metering is adopted by all companies; this enables them to fully understand consumption. It is assumed that all these smart meters are added to an Advance Metering Infrastructure solution, with information being processed at a sub-hour or hourly frequency. This removes uncertainty around seasonal consumption (such as Ramadan and during the summer) allowing DMA level water balances to be calculated, this makes sure that leakage can be identified all year around. It also allows for quicker identification of supply pipe leakage at a property level. There is an assumption that not all consumers are billed on the data from their meter. Non-household consumers are also added to the Advance Metering Infrastructure solution, enabling better insights for this segment of the industry. It is assumed that the increase in metering and needs of the water companies, incentivises the supply chain to produce a more accurate meter that better records low flow and needs to be replaced less often.
- **Smart networks, new sensors with advanced analytics –** all companies construct "smart networks" deploying appropriate sensors and developing analytics, that reduce the awareness times between a leak breaking out and it being located. The deployment of the sensors is prioritised by existing data, so that areas with the biggest impact would be targeted first. The need for a cheap reliable sensor drives the supply chain to innovate and meet the needs of the industry. This reduces costs and maintenance needs in the long run. Key valves are also monitored so that the integrity of the district meter areas can be maintained. With these large new data sets along with existing data, analytics begins to provide near real-time actionable insight to detection resources. This makes the detection resources more efficient and effective in pinpointing leaks, leading to reductions.
- **Progressive pipes rehabilitation –** based on the data from the smart networks companies are able to make a strong business case to increase the rate of asset renewal. Using the data gathered from the smart networks, the leakiest sections of the network are identified. This is combined with existing failure data to achieve an optimum replacement strategy. These sections are replaced in a manner that ensures that the new pipes are leak free for a considerable time. To achieve this there are a number of initiatives undertaken by the industry taking existing processes and learnings from the gas industry. These initiatives include developing methods to lay all new pipes in a leak free manner, improving the quality assurance of pipe-laying, ensuring that all fitters are trained and potentially accredited to a high standard, and developing design and production methods to reduce the number of joints in the system. Lining systems are also further developed and deployed where appropriate to further assist in reducing leaks on old pipes. Some trunk main renewal (or lining) will also be carried out to assist with leakage from this asset group.
- **Supply pipe replacement –** it is assumed that all lead pipes will be removed and replaced for water quality drivers. The new supply pipes will be designed to have as few joints as possible and will use the processes and techniques developed for pipe laying to ensure that the new asset does not leak. Other supply pipe materials are maintained in a similar way to current practices.
- **Optimum pressure managed networks –** as part of the pipes renewal efforts the whole system design is explored, this results in the assets not necessarily being replaced "like for like". This holistic system design means that further pressure management is achievable. This is also supplemented in rural areas with some solutions that allow pressure management for a wide area, that would historically not be achievable due to one or two properties at higher elevations.

4.6.1 Key areas of uncertainty

Many of the uncertainties exist in all the scenarios. In the development of the data and asset focused improvements scenario the main uncertainties considered were:

- **Costs of pipes rehabilitation –** the cost of pipes rehabilitation is expected to rise in this scenario at least to begin with, as contractors will need to follow more strict installation practices. However, efficiencies are likely to occur due to economies of scale due to the increased roll out. How these forces balance out will potentially have a significant impact on the cost of this scenario.
- **Cost of technology –** technology costs have the potential to rise (as has been seen in 2021 with a global shortage of microprocessor chips), but they can also reduce if market pressures, and efficiencies are exploited. This will make a significant difference to the overall cost of this scenario. The cost of a wide roll out of Advance Metering Infrastructure is also not fully understood. Potentially this could reduce if all utilities and other users share spare bandwidth of these solutions.
- **Leakage savings from asset renewals –** large, sustained leakage savings have not been seen from pipes renewals in recent times[20]. It is assumed in this scenario that methods and processes can be adopted that do allow for leak free networks to be laid, as is seen in the gas industry. However, if this is not the case then either more renewals would be needed to achieve the benefits or more active leakage control activities would be needed to make up the difference.

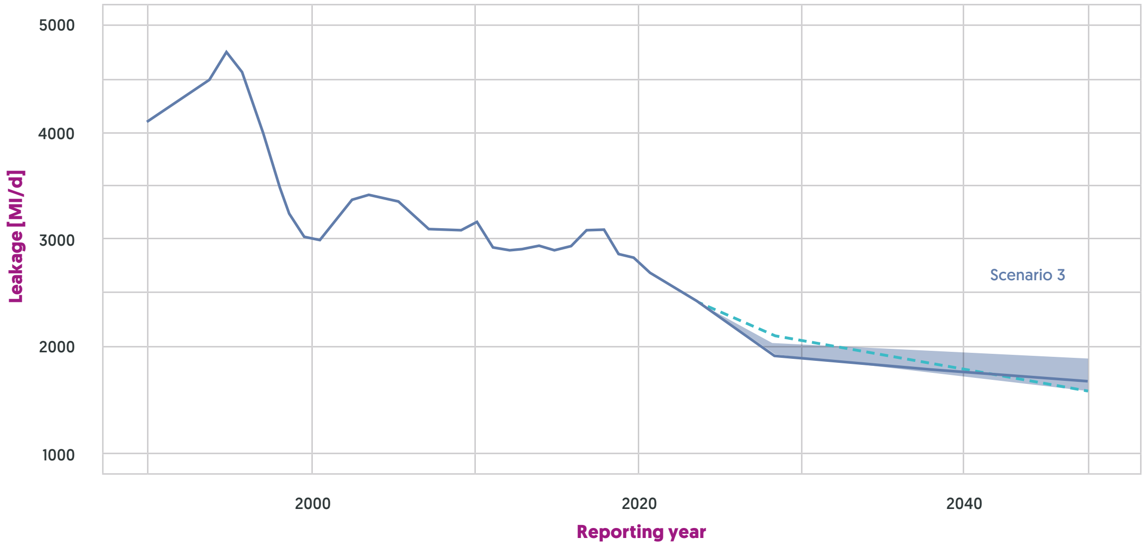
[20] Tripar UKWIR. The Impact of Burst-Driven Pipes Renewals On Network Leakage Performance (18/WM/08/67), November 2018

4.6.2 Benefits

Leakage

The rate of leakage reductions in AMP7 are increased into AMP8 and the PIC is achieved by 2030 as shown in Figure 4.7, as the worst performing areas of the network are renewed. The rate of reduction is then slowed between 2030 and 2050, as the pipe renewals become less effective due to the most "leaky" areas being targeted first and a much larger proportion of leakage now occurring on the customer side of the network. Due to this, central projection suggests that there would be a narrow miss of the NIC target in 2050.

Figure 4.7 – Leakage reductions to 2050 for the data and asset focused improvements scenario



Overall system

With pipes renewals optimised between leakage and bursts, the overall asset health of the UK network will improve. This will have additional benefits for interruptions to supply and network failures as the network will be younger.

The greater focus on a holistic approach to system design when doing pipes renewals will result in a calmer network than that seen today. This will result in a better designed network, which optimises pressure, delivering water efficiently to customers, while also reducing pumping activities. This will lead to less operational carbon from pumping, as well as reducing the electricity bills of companies. Using the data from the network and this more holistic approach areas where new developments (both commercial and domestic) are expected can be designed to be more future proof than they are today leading to less disruption due to developed activities.

The holistic design of the network will allow for easier reconfiguration of the network, so that customers can be brought back into supply more easily than is currently possible, if an incident does occur. The sensors associated with valves will ensure that the "as-designed" configuration is correctly returned after an incident.

It is anticipated that there will be more targeted active leakage control, meaning a reduction in the overall activities. This should lead to reduced operational carbon emissions that will assist with the carbon reduction PIC.

The removal of some of the old ferrous pipes will result in an improvement in water quality, as things like bitumen linings will no longer be in the network. Also, with the holistic design of the network, there is potential for networks to be designed so that they are self-cleaning and incorporate work done as part of the PODDS research.

Having a fully metered population will assist with consumption assessment, removing the need for unmeasured per capita consumption assessments. This will assist with water efficiency based activities and assist with targets to reduce consumption. This potentially opens the possibility of seasonal or time of day style tariffs to further flatten overall demand.

With all non-households having Advance Metering Infrastructure there will be significant benefits for MOSL and the retail sector. They will better understand consumption and so assist the non-household properties to reduce their consumption. Like with the domestic market, seasonal tariffs could be used to flatten overall demand, assisting with water consumption in potential drought or high demand conditions.

4.6.3 Risks and opportunities

A SWOT analysis was performed by the water company leakage practitioners, members of regulation teams and the authors. The outputs are summarised in Table 10 below.

Table 10 – Data and asset focused improvements SWOT analysis

SWOT	Scenario 3 - Data and asset focused improvements
Strength	**Fixing root cause** – By replacing the pipes that are leaking the most and putting in leak free networks, the industry would be tackling the root cause of the leakage problem. This approach has been seen to work internationally in places like Japan. This will also reduce the background leakage of the system, which in turn makes active leakage control more efficient. Hence this scenario has a reduced risk of not achieving the targets set by the PIC and the NIC. **Improved forecasting** – The larger data sets that will be produced combined with the analytics that will be employed will assist with forecasting of future leakage levels. This will also assist in the future requirements of different interventions as they will have less uncertainty around their performance. As well as assisting with prioritising of leak repairs to further improve the benefits.

SWOT	Scenario 3 - Data and asset focused improvements
Strength	**Leakage estimation** – With the increase in data, specifically around consumption (both total and night-time), leakage assessments would become more robust and based less on extrapolated assessments. With the use of accurate customers meters, then a DMA level daily water balance could be achieved which would be simpler to understand as well as more robust. **Better link to asset management** – The scenario more strongly links leakage to the overall network asset management process. Historically leakage has been seen as more of an operational activity, but with the focus on asset renewal and holistic design this link is improved. **Benefits to overall system** – As mentioned previously there are a number of additional benefits to the wider system that this scenario would deliver.
Weakness	**Customer supply side leakage** – With a large focus on the mains network and limited investment on the customer supply pipes, there is a potential that over time most leakage will be from these pipes as network leakage is resolved. Then to further reduce leakage a lot of smaller customer side leaks would need to be repaired which would cause a large amount of disruption for customers
Opportunity	**Sub-metering** – While doing pipes renewals sub-meters could be installed in key locations to further enhance the smart network and assist further with leakage pinpointing activities. **Leak free networks** – By replacing the worst performing areas of the network more time can be spent on areas that have not been a high priority in the past. These areas may be performing poorly, but never to the point where they have been looked at, with the worst performing areas now leak free these areas not performing as they should, can be examined. **Data analytics resource** – Jobs that involve advanced data analytics and problem solving with data, may be more attractive to people looking to join the water industry than the traditional view of people walking around with listening sticks. This new way of working could attract more people to the industry, ensuring that there are the resources required. **Improved resource mobilisation** – With the increase in insight, from the data and analytics, resources will be able to be mobilised more efficiently both to find and fix leaks. This provides benefits to the water companies, but also can assist with their relationships with key external stakeholders like councils and highways authorities.

SWOT	Scenario 3 - Data and asset focused improvements
Threat	**Limited resources** – Although the new jobs created in this scenario maybe more attractive to people, they do also make them more comparable to jobs in higher paying sectors such as banking and consultancy. This could mean that there is still a resource issue in the industry. **Regulation drivers** – Current regulation drives more short-term behaviour. The intergenerational benefits and economics of this scenario may make it difficult for water companies to make the business case to the regulator that this is the most appropriate course to take. **Increased bills** – This scenario is likely to increase bills to allow increased funding to reduce leakage. Water companies would have to present strong cases to their customers so they can make an informed decision on whether they fell that this is acceptable. Some water companies were able to make this case at PR19, but it is likely to be very regional. **Social impact of asset renewal** – Doing pipes renewals will impact the flow of traffic around cities and rural areas, that could have a substantial impact on the community. These rates will be much higher than they are currently, and so customers may not want the prospect of delays in order for this scenario to be delivered. **Interruption to supply** - The most effective ways to do pipes renewals also require the water to be disconnected for a period of time. With the current interruptions ODI this disconnection is counted against water companies' performance. To achieve the pipes renewals needed and the ODI, less optimal and more costly would need to be used, or new methods of pipes renewals developed.

4.6.4 Consideration of company characteristics

This option is likely to be significantly more expensive for the urban centers, such as London, Birmingham, and Manchester, due to council lane charges, as well as a more crowded underground infrastructure causing engineering difficulties. These companies may need to use different interventions in these areas to achieve the reductions required.

Rural areas are likely to be the last areas where Advance Metering Infrastructure is deployed, hence in these areas water companies may have to invest more to install masts to receive the data. Masts in rural areas may not be at full capacity increasing the unit cost of the infrastructure in these areas. There may also be issues with reception in some of the highly built-up urban areas and rural areas that would have to be overcome.

4.7 Progressive policies drive asset focus

This scenario is based on a change to the current regulatory framework that incentivises water companies in a different way to the current regime. There is an even greater focus on longer term benefits of options as well as how the customer supply pipes are treated. This scenario shows the potential of a regulation framework that is beneficial to leakage activities, and the extent of the leakage reduction that could be achieved.

The framework also provides a mechanism where interventions that have multiple benefits in different areas have easier methods to develop cost benefit assessments. This allows a more holistic approach to network design and interventions, but also allowing interventions that do not make a strong enough case when just one benefit is considered.

The framework also incentivises a further increase in sharing of knowledge around innovation, trials, insights and data. The attitude of the greater good of the industry ahead of inter-company competition, drives a more collaborative nature, where joint endeavors between companies are actively encouraged.

The interventions which contribute the most to this scenario are:

- **Adoption of customer supply pipes –** the regulation framework that is put in place allows the water companies to adopt the supply pipe from the boundary to the point to which it enters the footprint of the house. Similar to the adoption of private sewers in 2011, this would give the water companies greater powers to manage this group of assets. Lessons learnt during the private sewer process will be taken on board and used to ensure the potential benefits of this process are achieved. However, note that adoption alone doesn't fix the customer issues of working in and around properties, and further work is needed on the location and causes of supply pipe failures.
- **Progressive pipes rehabilitation –** under the new regulation framework there will be greater benefit for replacing older pipes that are failing or leaking, pipes that are found to be leaking prematurely are penalised with a new ODI that limits the number of new pipe leaks. Driven by the increased demand and the need to lay leak free networks, the supply chain and water companies work together to change practices, improving the reliability of new pipes and jointing systems. As part of the pipes renewals all supply pipes are replaced. This is done using one continuous pipe with no joints from the main, to the edge of the property's footprint as is done in the Netherlands. Lining solutions are developed that improve the performance of pipes where it would not be appropriate to replace the entire main. A new ODI around interruptions to supply during capital work is adopted, where with advanced warning customers can be disconnected for more than 3 hours.
- **Supply pipe replacement –** all supply pipes that fail are replaced in their entirety with one single piece of pipe from the main to the property's footprint. The need to do this in a cost-effective manner without digging up customer's drives and gardens, means that the supply chain develop new highly accurate moling techniques.
- **Smart metering and advanced data analytics –** during the pipes renewals, all customer meters are moved to the foundations of the house. All new meters are placed at the foundation of the property and new continuous supply pipes laid, so that universal metering is achieved. This removes the uncertainty around any consumption or supply pipe leakage going through the meter. Over time new highly accurate meters that can be attached to the outside of the pipe are developed meaning that a continuous pipe between the main and the customers internal stop tap can be used. All of the meters are attached to an Advance Metering Infrastructure, so that many of the benefits described in the "Data and asset focused improvements" scenario are achieved.
- **Smart networks, new sensors with advanced analytics –** to assist with proving that the new networks are leak free, manufactures develop intelligent pipes that use the Advance Metering Infrastructure to report back on their heath in near real time. Later these systems provide pinpoint locations of failures so that they can be quickly remedied, reducing overall runtime.

4.7.1 Key areas of uncertainty

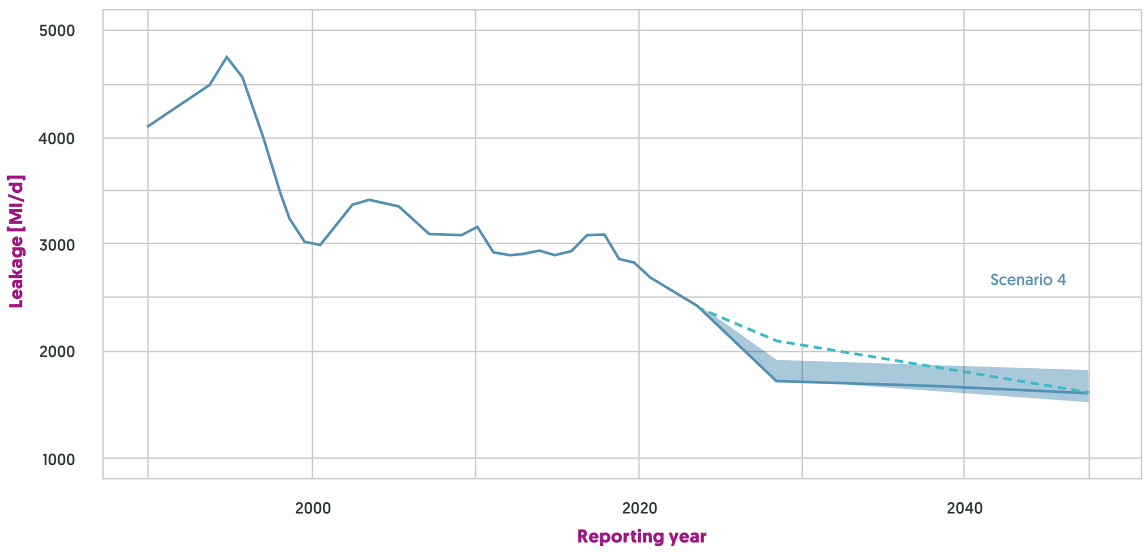
- **Costs associated with the adoption of supply pipes –** the costs associated with supply pipe adoption are not fully known and there are several factors and key decisions that will impact the total cost.
- **Costs of pipes rehabilitation –** the cost of pipes rehabilitation is expected to rise in this scenario at least to begin with, as contractors will need to follow more strict installation practices. However, efficiencies are likely to occur due to economies of scale due to the increased roll out. How these forces balance out will potentially have a significant impact on the cost of this scenario.
- **Leakage savings from asset renewals –** large, sustained leakage savings have not been seen from pipes renewals in recent times. It is assumed in this scenario that methods and processes can be adopted that do allow for leak free networks to be laid, as is seen in the gas industry. However, if this is not the case then either more renewals would be needed to achieve the benefits or more active leakage control activities would be needed to make up the difference.

4.7.2 Benefits

Leakage

With extensive pipes renewals and supply pipe replacement due to the adoption, the PIC target is overachieved in 2030 as shown in Figure 4.7, achieving the PIC in around 2027. With the worst performing network replaced along with the worst supply pipes, there are fewer benefits in subsequent years. Post 2030 there is less active leakage needed, as so much asset renewal has reduced leakage in the network.

Figure 4.8 – Leakage reductions to 2050 for the progressive policies drive asset focus scenario



Overall system

With substantial pipes renewals over the next 25 years the average age of the network will reduce, this will lead to better performance in bursts and interruptions to supply metrics. The adoption and replacement of all supply pipes will also allow for better optimisation of the network as a whole, further improving pressure and the overall performance of the system.

With an improved network there will be less active leakage control activities, this will help reduce the operational carbon associated with technicians driving around the network finding leaks. This will help the net zero carbon PIC.

The removal of old ferrous pipes will result in an improvement in water quality, as things like bitumen linings will no longer be in the network. Also, with the widespread pipe renewals combined with holistic design of the network, there is potential for networks to be designed so that they self-cleaning and incorporate work done as part of the PODDS research.

The removal of lead supply pipes also assists with water quality factors, providing efficiencies between the two programs where they exist. The improvements in moling also reduce the cost of lead replacements that are not done for leakage purposes.

Having a fully metered population at the property foundations will assist with consumption assessment, removing the need for unmeasured per capita consumption assessments. This will assist with water efficiency, based activities and assist with targets reduce consumption. This potentially opens the possibility of seasonal or time of day style tariffs to further flatten overall demand.

4.7.3 Risks and opportunities

A SWOT analysis was performed by the water company leakage practitioners, members of regulation teams and the authors. The outputs are summarised in Table 11 below.

Table 11 – Progressive policies drive asset focus SWOT analysis

SWOT	Scenario 4 - Progressive policies drive asset focus
Strength	**Wider system benefits** – The ability to make mixed benefit business cases, means that there are a number of shared benefits that improve the wider system as detailed previously. **Resilient** – This option has a very high probability of success compared to the other scenarios that have been examined. **Customer supply pipes** – The customer supply pipes are managed more like any other asset in the portfolio. This leads to asset health improvements through renewals and redesign. In turn this ensures the perception of leakage moving to the customer side of the network as network leakage is reduced. Due to a number of interventions that replace the supply pipe a large number are replaced with a single piece of pipe. This removes the joints which are commonly the initial leak locations. **Flexibility** – As the framework allows for corrections and changes to different pathways in a more flexible manner than is currently possible, a company can change their approach when new data or insights come to light. This ensures that they are always on the best value pathway. It also allows for the potential of a more capex dominated solution in rural areas and an opex solution in urban city centres, or vice versa. **Customer meters** – As universal metering at the property foundation is rolled out, the uncertainty between consumption and leakage is removed. Any continuous flows identify excessive use or internal leakage and can be more effectively targeted to help reduce per capita consumption. **Common goal** – The scenario is strongly focused around achieving the PIC and NIC targets as an industry, rather than as individual companies. This common goal will incentivise collaboration and joint innovation, bringing together leakage practitioners and strategists from across the country to achieve the "greater good".

SWOT	Scenario 4 - Progressive policies drive asset focus
Weakness	**Regulation change** – This scenario would require one of the biggest changes in regulation since privatisation. This could be a slow process as several consultations would be needed and the framework assessed for robustness and potential to abuse. This could potentially delay many of the measures outlined, so that the PIC in 2030 has to be achieved in another way. **Common methodology for cost assessment** – There is no common method for determining the cost per Ml/d of leakage saved. Without this style of uniform cost assessment, this style of regulation would be difficult to enforce. The variability in the assessment may also lead companies in similar positions down different routes of the adaptative pathway which would not be correct.
Opportunity	**World leading** – The leakage levels that would be achieved in this scenario would once again put the UK water industry at the forefront of leakage innovation and achievement. This would provide opportunities to the UK supply chain to further supply their solutions on the international market. **Alignment of climate change challenges** – The adaptive pathways process allows leakage strategy and delivery to be better aligned with climate change challenges that may occur in the future. **Generational expectations** – This strategy will cause a significant shift in how the water industry is viewed by the coming generations. Not only will this hopefully provide supporters of the industry in the future, but also provide a drive for people to be part of the sector. This could also lead to a more positive outlook from the media of the UK water industry which would assist with influencing stakeholders. **Water quality impact** – With the renewal of a large number of supply pipes, a number of lead connections are likely to be replaced. This will help with water quality compliance and would likely allow for efficiencies of delivery for the two programmes.
Threat	**Best value framework** – The best value framework for leakage will likely cause other areas of the sector to be poorly funded. Trade-offs are always required to balance all the requirements of the industry and hence the regulatory framework described in this scenario maybe unobtainable.

SWOT	Scenario 4 - Progressive policies drive asset focus
Threat	**Supply pipe records** – The industry would take ownership of a large number of assets where records are poor. This was an issue when the private sewers were adopted, and so hopefully learnings from this process can be taken through into the customer supply pipe adoption. **Customer willingness to pay** – This option has been shown to be more costly than other scenarios, there is potential that customers will not be willing to pay for this level of investment. This would likely push the leakage burden on to the next generation. **Social impact of asset renewal** – Doing pipes renewals will impact the flow of traffic around cities and rural areas, that could have a substantial impact on the community. These rates will be much higher than they are currently, and so customers may not want the prospect of delays in order for this scenario to be delivered. **Further reduction** – Once the 50% reduction target is achieved in 2050, the public regulators and the environment may require further reductions. The capability of the industry at this stage would have to be revaluated, to see if further reductions were possible. **Failure of scenario** – This scenario combines many of the requirements that have been identified by leakage practitioners that would be needed to achieve leakage. If it does not work, then the industry has limited other options to reduce leakage. However, many of the interventions in this scenario have been shown to work in parts of the UK and internationally, so it is believed the complete failure of this option is unlikely.

4.7.4 Consideration of company characteristics

Urban areas, where there is a higher density of population, will have a large number of supply pipes to replace. Supply pipe records for these companies are varied, those with poorer records may need to do detailed surveys of the supply pipe network before it can be managed effectively.

Common or shared supply pipes are also an issue that need to be overcome, certain companies have a high proportion of these types of assets and adopting them will come with additional issues. Experience from the sewer adoption work will assist in this area, with methods that have already been proven.

Rural companies may find that although they have a smaller number of supply pipes, these may be very long, for example a farm building may be several kilometres from the current metering point. These assets will need to be managed in a different way to the more normal supply pipe that is in a suburban street. Adopting these assets could also pose a risk in terms of increased replacement costs due to more complex works.

4.8 Cost comparison of scenarios

The high-level cost modelling of the different scenarios has provided a national perspective in relation to the increase in costs of scenarios 2, 3 and 4 relative to scenario 1. The range of costs varies considerably, as demonstrated in Figure 4.9 and Table 12.

Figure 4.9 – Cost Comparison of Scenarios

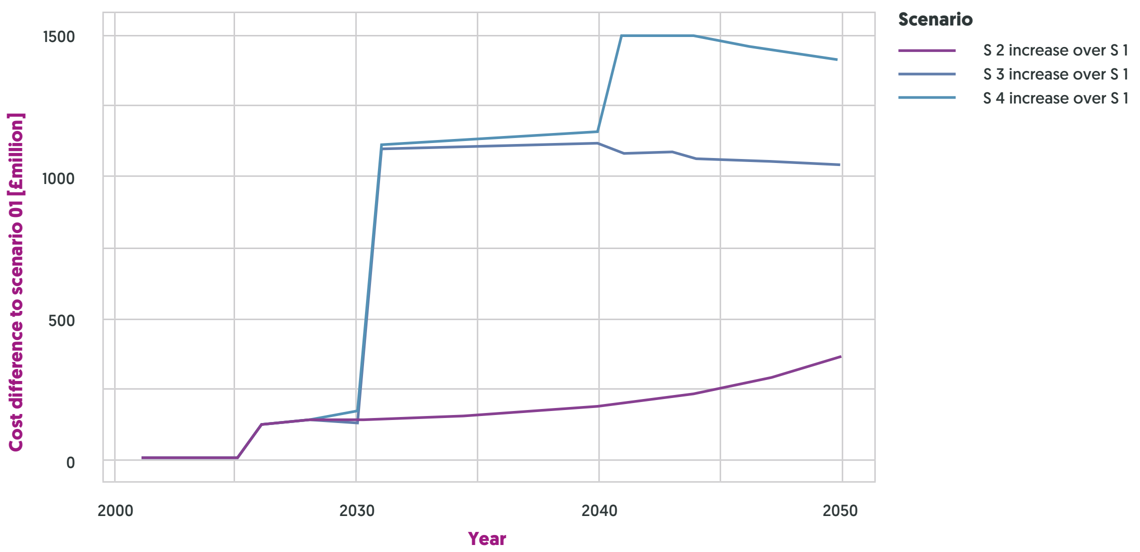


Table 12 – High-Level Cost Increase by Scenario to 2030 and 2050

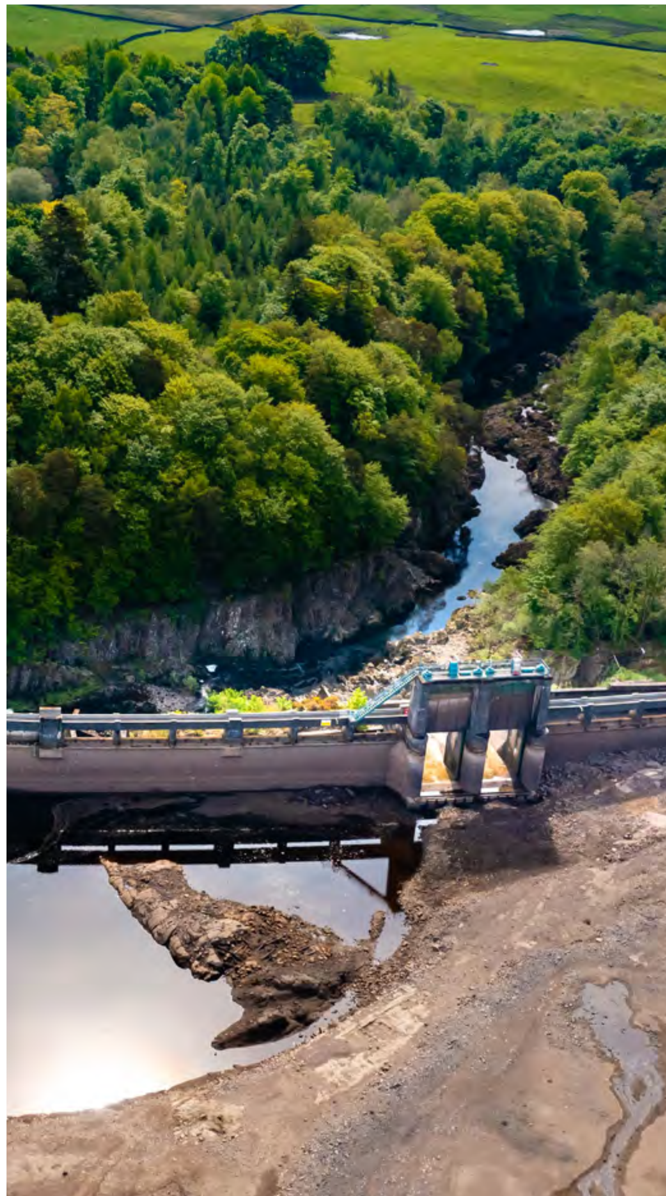
	NPV difference compared to limited low-hanging fruit (S-01) (£million)		
Year	**Smarter networks (S-02)**	**Data and asset focused improvements (S-03)**	**Progressive policies drive asset focus (S-04)**
2030	518	520	556
2050	2,620	11,510	13,358

The high-level cost assessment itself does not paint the full picture, and a number of considerations need to be made:

- Scenario 2 is not automatically the best pathway due to being the lowest cost approach, as risks and sensitivity to key inputs and parameters result in this being more likely to fail to achieve the 2050 target in comparison to scenarios 2 and 3.
- There are wider benefits above and beyond leakage, particularly in scenarios 3 and 4, such as water quality, customer service and resilience benefits that are far less prevalent in scenarios 1 and 2.
- Scenarios 2 and 3 may not adequately mitigate risks that asset deterioration might pose. There is a robust understanding of network deterioration with respect to bursts, however deterioration and increase of background leakage with an ageing network is a potential risk that could result in smart networks and enhanced ALC interventions failing to deliver the longer-term targets. There is a significant gap in knowledge and understanding today, in relation to such potential risks, associated with both company networks and customer supply pipe assets.
- Scenarios 2 and 3 may be at greater risk of "Black Swan" type events and significant disruption to communications networks in comparison to Scenario 4, for example cyber-warfare or solar flare type risks that are of low probability but extremely high potential consequence.
- The starting point of companies is variable, and it has to be recognised that the national picture will not necessarily translate into the pathway or scenario an individual company should take.

The high-level modelling does set out a clear message however, and that is despite the 2050 target being a significant challenge, with some additional effort, significant reduction appears to be possible, and the key question is around how to achieve long-term reductions in an affordable way for customers.

In achieving the PIC, an increase in costs is required based on high-level national modelling. The achievement of the 2050 target is highly sensitive to inputs and assumptions in scenario 2 which represents a greater risk of not being able to achieve the 2050 target compared to scenarios 3 and 4. It may be the case that scenario 2 is not able to achieve the 2050 target at all, and therefore if other pathways are needed, a significant step-change in costs between 2030 and 2050 may be necessary.



4.9 Initial adaptive pathway

Having investigated the scenarios, it is useful to consider what an adaptive pathway might look like at a national level from the current time. As highlighted earlier a large unknown at present is the level of background leakage, which restricts how far leakage can be driven down.

Figure 4.10 shows the leakage paths for the four scenarios normalised to a per property level, considering the expected growth in population and housing.

These are then overlayed on the range (the 25th and 75th percentiles) of estimated background leakage levels (based on 2020 data).

Figure 4.10 – Leakage scenarios compared with background leakage estimates

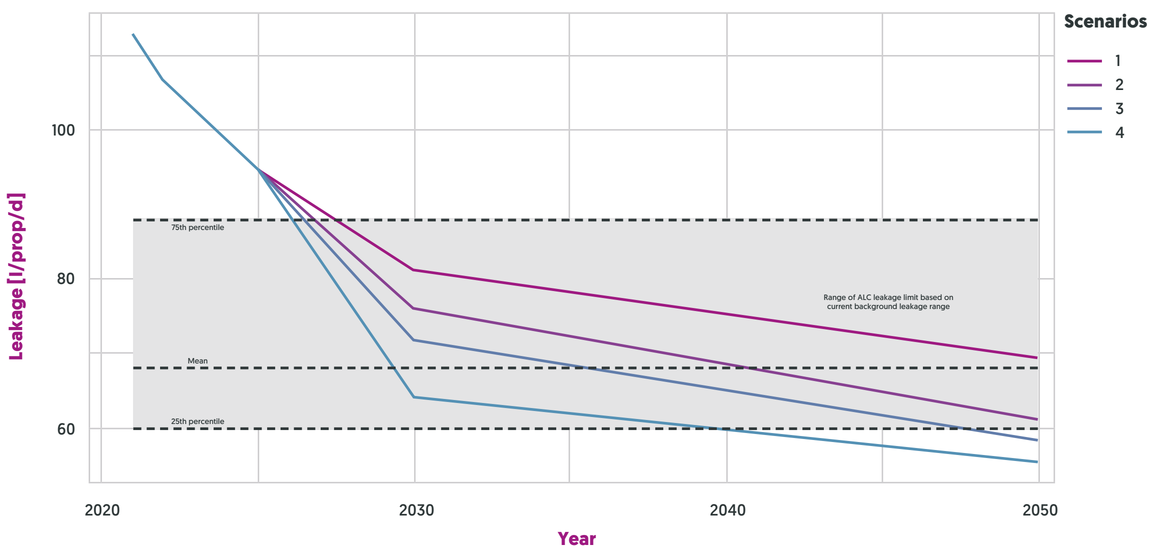


Figure 4.10 indicates that it should be possible to meet the PIC 2030 range (scenarios s_02 and s_03) without the need for increased asset replacement. However, this relies on the current estimate of background leakage being correct, and therefore at the current time, this still carries a degree of risk. However, using this as a starting point an initial adaptive plan can be bit up from the elements of the 4 scenarios as follows:

a. Assume that AMP7 ODI targets in 2025 are met using the current AMP7 leakage reduction plans.

b. Current developments in optimising the pressure in networks, smart metering of properties and smart sensors for smarter networks are encouraged in AMP7.

c. Work is carried out in AMP7 to improve the assessment of background levels of leakage and customer side leakage, these allow the adaptive pathway to be modified accordingly.

d. From 2025 most areas are implementing optimum pressures in the network to reduce leakage and background levels of leakage.

e. From 2025 there is an increase in smart metering of properties, starting in the south east and east, and being adopted in other areas beyond 2030.

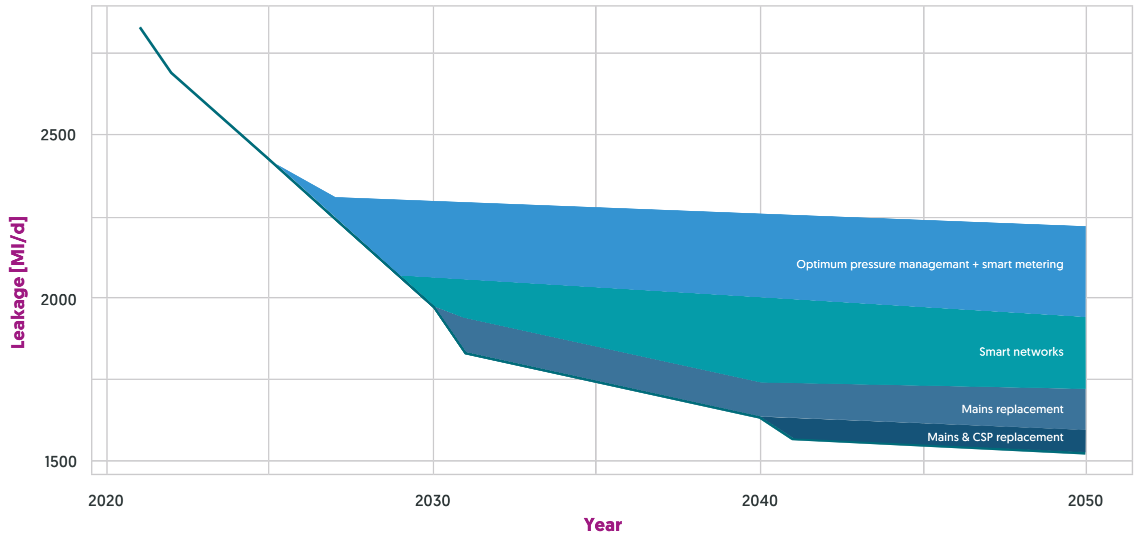
f. From 2027 there is an increase in smarter networks in some areas, which grows to other areas beyond 2030.

g. The current assumption is that some form of asset replacement will be required from 2030 as the limits on background leakage are approached. At the current time this is set to an additional 1% of the network being replaced every year. This is leakage driven and will reduce leakage and background leakage.

h. Beyond 2040 further asset replacement and customer supply pipe replacement will be required to meet the 2050 target, therefore an additional 1% of the network is being replaced every year from 2040.

The modelled pathway for this is shown in Figure 4.11.

Figure 4.11 – A potential pathway to the NIC target in 2050



Using the costs modelled from the scenarios:

- the net present value costs over projected business as usual from 2020 out to 2030 are £420 million,
- the net present value costs over projected business as usual from 2020 out to 2050 are £12,750 million.

This assumes current prices, and the opportunity would be to drive down the costs of asset replacement through innovation.

SECTION 05

Next steps for the Sector

Commitments by Water UK and Water Companies

There are a number of commitments needed from Water UK and Water Companies to complete the development of the leakage route map. There is also the assumed commitment of the achievement of the AMP7 targets as set out in the PR19 business plans. These are set out below.

Best-value decision framework for adaptive pathways (Dec 2021/Jan 2022)

In advance of Ofwat publishing PR24 guidance, it is recommended that the industry sets out a relatively consistent approach through developing a best-value decision framework that helps to demonstrate the most appropriate ways for specific companies to reduce leakage. This is necessary for setting out a progressive dialogue as over the longer-term there may need to be increased level of asset renewal to support the long-term ambitions to reduce leakage.

At PR19 some of the tensions between Performance Commitments, for example between leakage and pipes bursts, is perhaps indicative of companies having not been able to articulate clearly enough the pathways to reducing leakage.

By comparing a number of different scenarios and interventions, the aim is to demonstrate that the preferred approach represents the best-value approach, and will need to set out the internal or external factors and changes that might influence the pathways chosen in the long-term.

The WRMP process is weak in certain aspects, in particular with inconsistency in what leakage options are included or not and the level of granularity. For example, some companies input leakage reduction options, others broke this down into specific intervention types e.g. ALC, pressure management. Leakage options in the WRMP do not account for wider benefits, and therefore this process does not generate a holistic leakage strategy.

It will be necessary to make decisions in relation to the adaptive pathways for leakage reduction, taking into consideration wider costs, benefits and risks, in a way that is consistent with wider business planning options and investment needs.

Setting out an approach to determine best-value approaches will help companies to justify the pathway that they choose as the preferred approach, and influence regulators in terms of establishing a more progressive dialogue.

It may be sensible for the industry to demonstrate that for a range of scenarios, the costs/benefits/risks for leakage reductions of 30%, 40% and 50% as this may highlight significant step changes in costs of delivery of holistic leakage strategies, and this would be valuable insight for input into WRMPs and regional plans.

Information and knowledge sharing (Mar 2022 - ongoing)

The industry will need to develop and find effective ways of sharing information at a sufficient level of detail that doesn't necessarily share sensitive detail, but can help other companies understand what solutions, technologies, processes, innovations and interventions work effectively and to help companies all making the same mistakes and accelerate learning in terms of reducing leakage levels. The industry has been generally working to achieve SELL for a number of years and leakage levels have been relatively flat or reducing slightly. For leakage levels to be reduced significantly in AMP7 and beyond, sharing key lessons learnt will be essential. A mid-AMP7 knowledge share in advance of PR24 may be highly beneficial in developing adaptive pathways.

Due to the regulatory regime this sharing is not always to be the benefit of the individual company, but is for the "greater good" of the industry. This sharing of information should be encouraged as it reduces duplicate effort and allows innovations to be benefitted by all more quickly. However some mechanism should be considered so that the companies are rewarded for this sharing.

Improved quantification of background levels of leakage (Sep 2022)

There are considerable risks in relation to the level of background leakage for companies, in terms of choosing a best-value pathway in the long-term. If background leakage is lower than current estimates, this may favour approaches that reduce the awareness time of existing leakage e.g. ALC, smart networks. If background leakage estimates are similar or higher than current estimates, this may favour or indeed require a greater proportion of asset rehabilitation. There is considerable sensitivity in terms of which pathways represents best-value based on high-level modelling of costs and different interventions, with respect to background levels of leakage.

The long-term pathway requires a more robust and improved estimate of background levels of leakage. This will need to factor in a number of considerations:

- Whether background leakage is actually leakage, or something else such as plumbing losses.
- What can be achieved with the best current ALC and associated technology.
- What can be achieved with smart metering or smart networks solutions.
- What other factors influence background levels of leakage e.g. pressure, topography, soils, weather etc.
- Whether background leakage can be identified using advanced data analytics and/or improved condition assessment.
- Understanding if targeting bursts also reduces background levels of leakage, or if the latter is spread across the entire network.
- Understanding the level of background leakage on new networks.
- As AMP7 leakage is reduced, ensuring the approaches challenge current policy minimum levels of leakage, and don't just stop at the current policy minimum as soon as it is reached.

The commitment will require sharing of knowledge and data, as well as a collaborative approach to better understanding the quantification of background leakage

Improved quantification of customer side leakage (Sept 2022)

Customer side leakage is occurring on assets that the water companies are not responsible for, however contributes to the total leakage volumes that are reported by companies. There is generally a lack of data and information in relation to the asset information, and the risk of supply pipe asset deterioration is a significant "known unknown" that could put long-term aims at risk.

The estimation of customer side leakage has historically been extremely uncertain, based largely upon bursts and background (BABE) type methodology. With the increasing prevalence of AMR/AMI and associated data improvements, a commitment is needed to firstly improve the quantification of customer side leakage today.

Secondly, the industry needs to begin to better understand the potential risks associated with asset deterioration of supply pipes. Along with the interaction between the lead supply pipe replacement programmes that many companies are currently undertaking and the levels of leakage. Understanding these two vital areas will help to guide future decisions around this key asset group.

Quantify the scale of supply chain resource constraints and opportunities (Sept 2022)

Depending on the preferred pathways chosen, resource constraints may play a significant role in determining whether the pathway can be successfully delivered in a timely manner.

A pathway that focuses on additional ALC activity may encounter skills shortages, as other sectors and industries compete for technical resources. This may represent a risk if additional staff are required, however an opportunity could be to upskill the existing pool of ALC resources, to deliver greater benefit and provide greater valuation of the skills that may be needed as technology and innovation further improves and evolves.

An approach requiring significant numbers of sensors may need to consider whether there are opportunities to be gained through economies of scale, or whether underlying drivers risk pushing up the cost of certain raw materials or key components such as computer chips.

The commitment is required for the water companies to engage with all supporting elements of the supply chain to understand better the potential risks and opportunities, and two-way discussions with the supply chain may provide benefit in helping them to solve some of the challenges that the industry faces. For example, it may be beneficial to help drive market forces by setting out how cheaper sensors providing greater coverage may be help changing the economics of managing leakage in the longer-term.

Improved asset renewal selection based on leakage and asset health (Sept 2022)

As the longer-term achievement of 50% reduction from current levels by 2050 appears likely to require more progressive asset renewal strategies, it will be necessary to improve the approach and processes in relation to the selection of asset renewal. This will require the following considerations:

- Better targeting of asset renewal in terms of leakage, not simply pipes bursts.
- Understanding if it is indeed possible to target background leakage through pipes rehabilitation, without resorting to entire DMA asset rehabilitation.
- Understanding the optimum balance between data analytics, asset deterioration modelling and physical data collection in relation to asset condition and how these relate to asset performance.
- Improving the processes in relation to delivering asset renewal that benefits leakage and wider asset health considerations. For example, is the industry gathering enough asset condition data and would gathering more or better-quality data improve the overall cost-effectiveness of asset rehabilitation?
- Understanding the benefits of targeting communication pipes and service pipes for rehabilitation.
- Improvements in understanding pre and post benefits of asset rehabilitation
- Improved understanding of how asset deterioration affects leakage and not simply bursts, including communication pipes as well as distribution network assets.

Development of a code of practice on how to lay pipes without leaking (Dec 2022)

Assuming that population growth over time will result in a proportional increase in the length of network overall, and that current approaches are not resulting in leak free or ultra-low loss new networks, it is critical that a code of practice is developed, as an improvement to the nearly leak free networks that are currently produced. There may be technological improvements required in order to reduce the risk of human elements of the asset installation process resulting in joint or other failures over time on new networks. It may also be possible that the current materials and joints are sufficient, but that installation practices are not rigorous enough with insufficient quality controls, and that improvements in workmanship and supervision could suffice. It may also be needed for the industry to produce and run an accreditation scheme for laying pipe so that the standards are as high as possible.

Laying new networks that are fully resilient to future problems is a vital step, as each passing year where new network is installed and not delivering leak free new networks, is making the long-term aims more difficult to achieve.

The following considerations are required:

- Improved quantification of losses on new networks. This may be achieved through policy change where new developments are discretely monitored as standard, developments above a certain threshold in terms of number of properties, to improve the understanding of the extent of leakage on new networks.
- Improved understanding of the benefits of improved workmanship and supervision. i.e. what are the long term savings over the course of a pipes life of making the highest quality joints and checking them before they are buried.
- How a new Code of Practice can benefit the long-term forecasts and understanding to what extent improvements could reduce the requirement for additional effort to be necessary in order to stand still with respect to total leakage in volumetric terms.

Decision on customer supply pipe strategy (Dec 2022)

The industry will need to talk to the regulators and the public to determine the best method to deal with customer supply pipe leakage. This may be the adoption of supply pipes of (some or all pipes) or a new mechanism to assist customers with repairs or replacement. Based on the commitments above, the industry should have sufficient information to have a fully informed debate on what the best route is for this asset group. This will be a longer term commitment with the initial conversations occurring around this time, it is expected that if adoption is pursued this would be the latest point at which initial conversations could begin for a change at the beginning of AMP9.

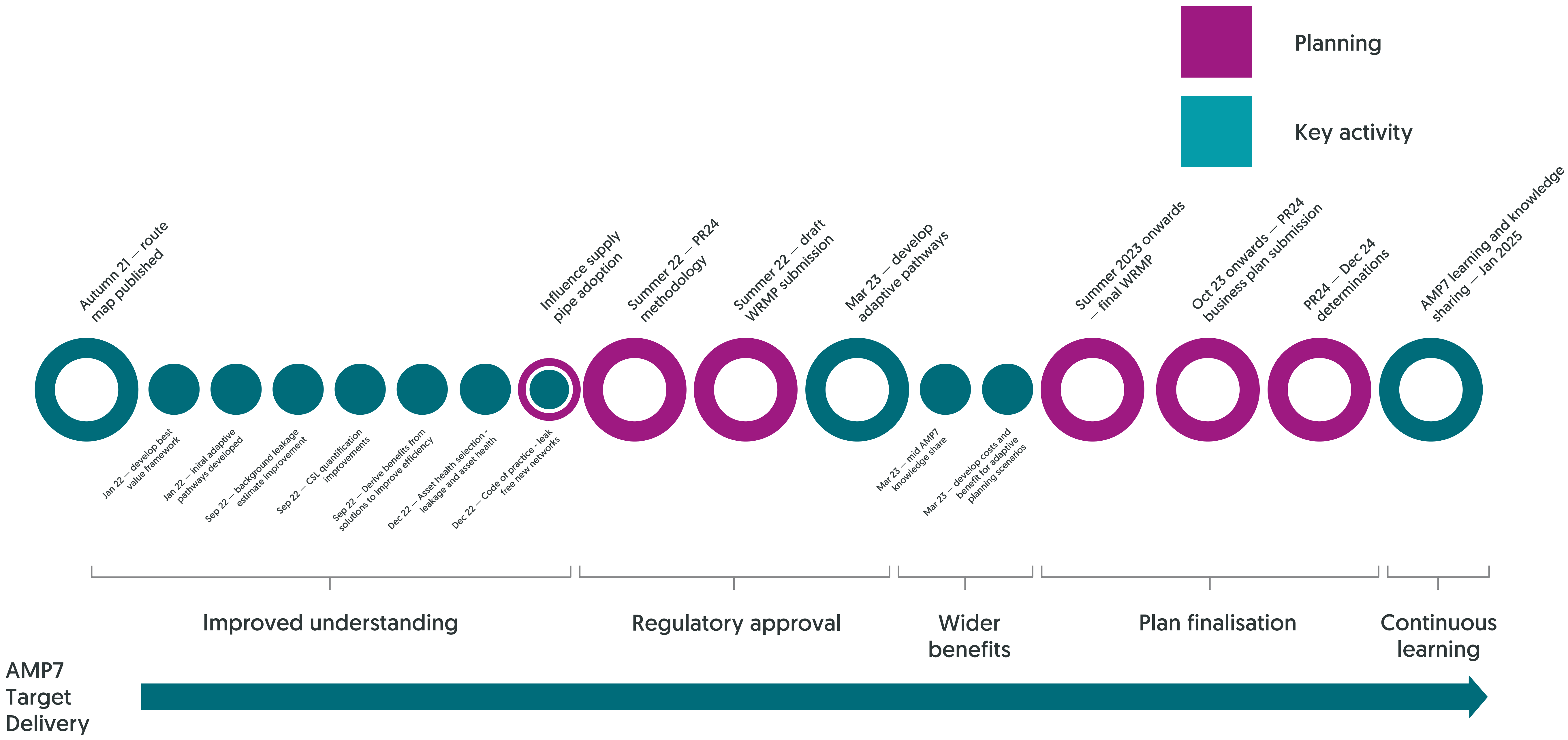
Development of costs and adaptive pathways scenarios (Mar 2023)

The industry will need to commit to developing adaptive pathways and scenarios that are specific to individual companies, but allow the industry to demonstrate it is taking a best value approach to reducing leakage. Best value will need to be considered in the short and long-term lenses, and companies may need to consider:

- Assessment of the costs and benefits of delivering the four scenarios as a minimum and comparing with what can be achieved through ALC alone.
- The costs of reducing leakage by 40%, 50% and 60% from current levels
- Demonstrating sensitivity e.g. what if sensor costs were 50% lower, or if asset renewal costs were 20% greater.
- Factoring in externalities such as carbon (operational and embedded)
- Considering social costs and benefits. This should extend to the ability to export the expertise derived from these activities and the positive impact this could have on the economy.
- Considering other external factors such as climate change, or Councils imposing more stringent road charging schemes or penalising reactive failures of networks.
- Development of the thinking in terms of what the tipping points are, and how and when to make decisions around adapting e.g. each AMP or more frequently?

The commitments and decisions have been outlined in the timeline shown in Figure 5.1.

Figure 5.1 – Commitment timeline for AMP7



Conclusions

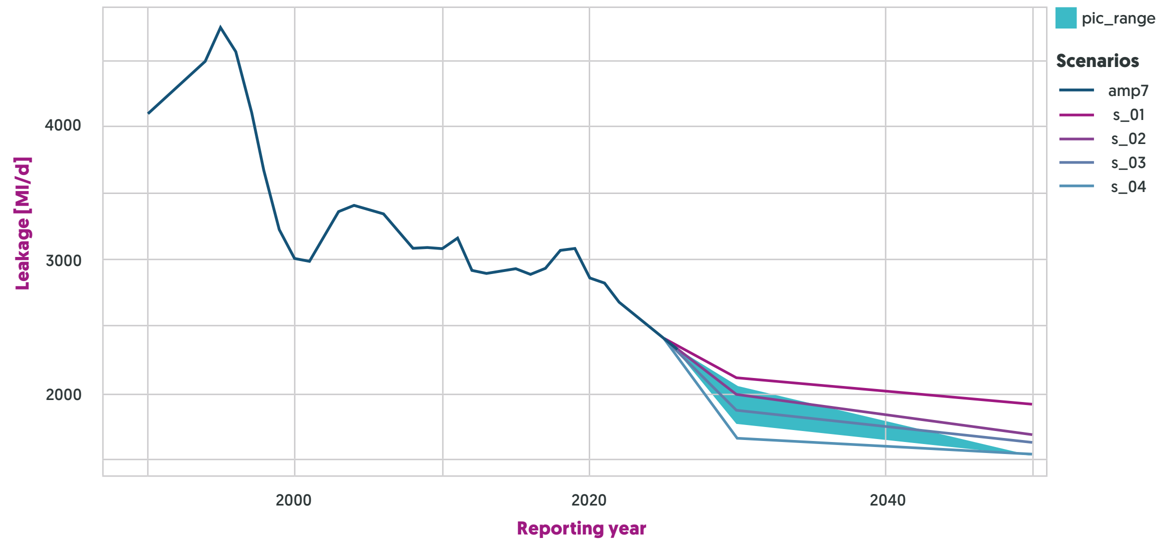
In conclusion, a robust process and approach has been presented that allows the industry and individual companies to achieve the PIC and NIC targets as set out. The current levels of leakage as well as the historical reductions achieved, network age and geographical constraints of different companies, means a "one size fits all approach" would not be appropriate.

There is also some significant uncertainty around things such as background leakage and customer supply side that will have an impact on what is the most appropriate pathway. Instead, we have laid out an adaptive pathways approach which looks at interlinked pathways to achieve the leakage reductions required.

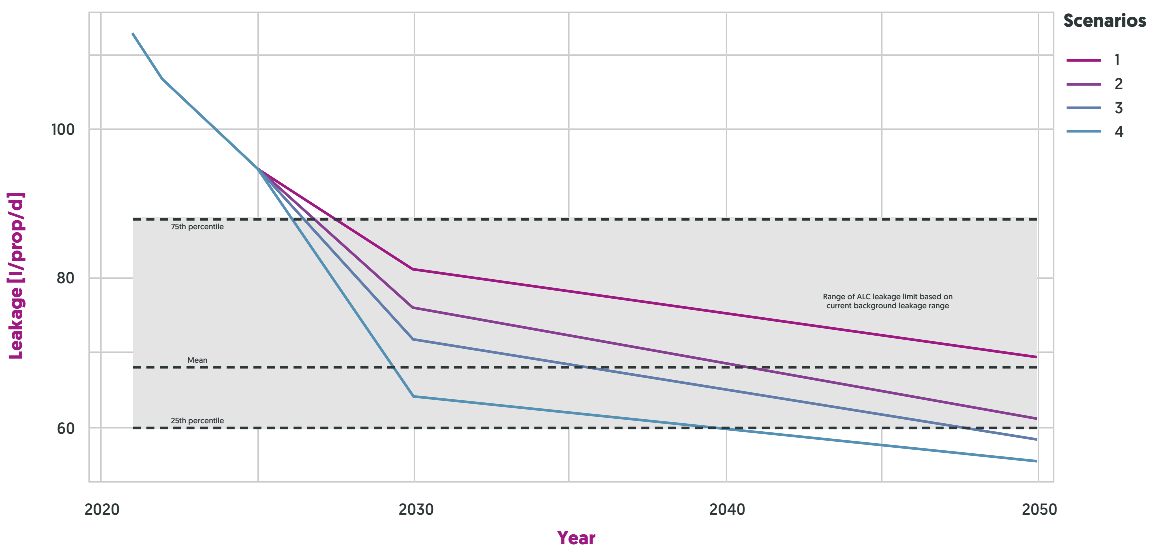
This framework allows companies to determine the approach that is most suitable to the constraints that they have, as well as looking to see if a change in strategy is required to achieve the targets. We have proposed four scenarios that are potential paths through the adaptive pathways, each of which look at a different possible future with different focuses.

- Limited low hanging fruit
- Smarter networks
- Data and asset focused improvements
- Progressive policies drive asset-focus

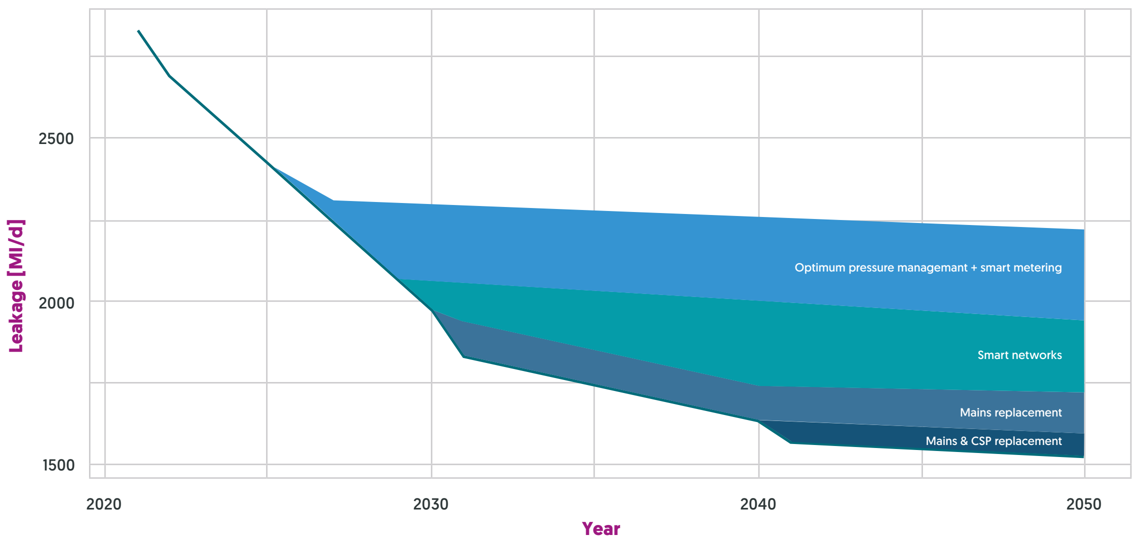
The leakage saving for each scenario is shown below.



Based on the modelling we have undertaken, we do believe that both PIC and NIC targets are achievable, but will require changes in the way that leakage activities are done and also funded. The leakage forecasts in the WRMP19 very nearly meet the 2030 PIC target and achieve the NIC targets in 2050 on a national level. However as can be seen in the figure below the risk of not achieving the targets associated with limited low hanging fruit and smarter networks scenarios are higher than the other two scenarios as they have less impact on the background leakage. As has been discussed it becomes increasing harder to achieve leakage savings with active leakage control as you get nearer to background leakage levels. As there is minimal movement of the background leakage levels in these two scenarios, the risk of failure is much higher.



In reality a water company would not follow one scenario, but use the adaptive pathways approach to move between the scenarios at key points, an example of this is demonstrated below.



In order to achieve the targets, a number of key commitments need to be made and completed in the next 18 months.

All of these commitments are needed before the PR24 methodology is set out and in time to be part of the dWRMPs. This will ensure that sufficient leakage reductions are stated for AMP8, but also the industry has time to collect the required evidence to make the case to the regulators of the scale of the funding that will be required to achieve these reductions.

The commitments are

1. Best-value decision framework for adaptive pathways
2. Improved quantification of background levels of leakage
3. Improved quantification of customer side leakage
4. Quantify the scale of supply chain resource constraints and opportunities
5. Improved asset renewal selection based on leakage and asset health
6. Development of a code of practice on how to lay pipes without leaking
7. Information and Knowledge Sharing
8. Development of costs and adaptive pathways scenarios
9. Decision on customer supply pipe strategy

Appendix A

Cost Modelling Assumptions

A.1 Scenario 01: Low hanging fruit

Scenario 1 relies on the continued evolution and improvement of active leakage control (ALC) and maximising the opportunity to optimise pressures in the network to reduce background leakage further. Leakage costs are modelled for steady state conditions (countering the impact from leak breakout and growth) and for reducing leakage each year (transitional costs).

A.1.1 Modelling ALC costs

The steady state costs are modelled using Method A from the Tripartite economic level of leakage report. This relies on estimating the total number of leaks that break out each year and the cost of finding (active leakage control costs) and repairing those leaks. The active leakage control costs are sensitive to the background level of leakage, and the costs rise exponentially as leakage approaches the background level. We therefore make an assumption that the steady state costs increase from year to year as the level of leakage reduces.

Method A calculates the leakage cost curve as follows:

$$C = \frac{K}{(L - L_{BL})}$$

Where:

C *is the total ALC cost at a given leakage level*

L *is the leakage level*

K *is a coefficient*

L_{BL} *is the background level of leakage*

$(L - L_{BL})$ *is the excess leakage level*

The coefficient (k) is calculated in the base year from:

$$K = C_{BY} \times (L_{BY} - L_{BL})$$

Where:

C_{by} *is the ALC cost in the base year*

L_{by} *is the leakage level in the base year.*

The cost of reducing leakage using active leakage control (transitional cost) is modelled by estimating the number of additional leaks that need to be found and fixed each year to lower leakage, again using the Method A approach. This can only be done where the leakage level is above a value determined by the background leakage and the amount of leakage reported by people spotting leaks and bursts.

We have modelled the impact of optimising pressure in the network by progressively lowering the pressure in the network and calculating the impact on the background leakage level. Lower pressure will lower the background leakage level, making it possible to use ALC to drive leakage down further. We have assumed that innovation and evolution of ALC technologies and data insight will counter the challenge of finding leaks at a lower pressure.

A.1.2 ALC assumptions

For the base year Method A leakage model:

Year	Value	Units
Total leakage	2830	Ml/d
Trunk mains and service reservoir leakage	300	Ml/d
Detected repairs	120948	#
Reported repairs	181422	#
Steady state leakage costs	58,055,230	£/year
Mean run time for detected repairs	10	days
Mean run time for reported repairs	5	days
Mean awareness time for detected repairs	235	days
Mean awareness time for reported repairs	5	days
Mean flowrate for detected repairs	0.15	l/s
Mean flowrate for reported repairs	0.16	l/s
Transitional detected leak flowrate	0.012	l/s
Background leakage ratio (BL:total leakage)NB1	0.5	ratio
Location cost	480	£/leak
Repair cost	600	£/repair
Marginal cost of water	100	£/Ml
Property count	26,435,000	#

NB1: The background leakage ratio in the base year has been derived from a set of background leakage estimates for 16 companies with a mean ratio of 0.5, a 25th percentile of 0.425, and a 75th percentile of 0.6.

There is an assumption that ALC costs increase exponentially over time as runtimes are reduced and smaller leaks need to be detected.

A.1.3 Pressure modelling and assumptions

The **impact of pressure** on background leakage is modelled using the equation:

$$\frac{L_1}{L_0} = \left(\frac{P_1}{P_0}\right)^{N1}$$

Where:

Pressure is reduced from P_1 *to* P_0

Leakage at $P_0 = L_0$

Leakage at $P_1 = L_1$

N_1 *is the leakage/ pressure exponent*

We assume that $N_1 = 1$.

We assume that pressure is reduced by 5m per head from 2025 to 2030, and by a further 5m head from 2030 onwards.

A.2 Scenario 02: Smarter networks

Scenario 2 relies on the continued ALC and optimised network pressure along with an introduction of smart meters with data analytics, smart network sensors with data analytics, and improved repairs.

A.2.1 ALC modelling assumptions

We use the same model and assumptions stated for scenario 01 for those areas of the network that do not have smart sensors.

A.2.2 Smart meter assumptions

We assume that in AMP8 companies in the south east of England transition to smarter metering with data analytics, and from AMP9 onwards other companies transition to smart meters. We assume that smart meters allow services with high continuous flows to be identified and then targeted to reduce leakage, resulting in a 10% improvement in leakage efficiency.

The marginal costs of smart metering are assumed to be £8 per property per year.

A.2.3 Smart network assumptions

We assume that smart sensors start to be rolled out after 2030, following a period of innovation to reduce the cost of fixed network sensors. We do not assume any specific type of sensor, only that the deployment of smart sensors will allow leaks to be found more quickly at a lower cost.

We assume that sensor coverage is 20% of the network, and that sensors have an equivalent annual cost of £150 each, and that sensors are deployed every 200m.

For that part of the network with smart sensors, we adjust the ALC method A model to take account of a lower time to find each leak. We assume that for smart network areas leaks can be found in 9% of the time of non-smart areas.

A.2.4 Improved repair assumptions

We assume that innovation in repair techniques improves the effectiveness of each repair.

A.3 Scenario 03: Data and asset-focused improvements

This scenario assumes the improvements in sensors and data discussed in the previous scenario, with the introduction of asset renewals.

A.3.1 Asset renewal assumptions

For this scenario we have assumed that an additional 1% of assets are replaced each year from 2030 onwards. Assets are assumed to be installed such that they don't leak, and replacements are targeted to reduce leakage. Hence asset replacement reduces both leakage and background leakage.

Costs for asset replacement are derived from TR61 as follows:

	Cost (£/m)			
Mains size (mm)	**DD_PB**	**Sliplining**	**Mean**	**Proportion**
50 to 99	120.8	141.7	131.25	30.11
100 to 199	184.85	222.85	203.85	44.23
200 +	664.76	806.53	735.64	25.66

Form this a mean weighted cost per metre of £318.45 is used to calculate the cost of asset renewal per year. An additional £10 per metre is added for increased QA and resources to ensure leak free installation.

A.4 Scenario 04: Progressive policies drive asset focus

This scenario assumes the improvements in sensors and data, and the introduction of asset renewals discussed in the previous scenario.

A.4.1 Additional asset renewal assumptions

For this scenario we have assumed that an additional 1% of customer supply pipes (CSPs) are replaced each year from 2040 onwards. CSPs are assumed to be installed such that they don't leak, and replacements are targeted to reduce leakage. Hence their replacement reduces both leakage and background leakage.

Costs for asset replacement are derived from TR61 using the small mains costs:

	Cost (£/m)			
Mains size (mm)	**DD_PB**	**Sliplining**	**Mean**	**Proportion**
50 to 99	120.8	141.7	131.25	30.11

From this a mean weighted cost per metre of £131.25 is used to calculate the cost of CSP renewal per year.

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