The long term potential for deep reductions in household water demand

Artesia Consulting

Produced for Ofwat

26th April 2018

This report has been designed to be read on a computer or tablet screen, please think of the environment before printing, thank you.

Report Reference:	AR1206
Client:	Ofwat
Author(s)	Rob Lawson, Dene Marshallsay, Daniele DiFiore, Sarah Rogerson, Shana Meeus, Joseph Sanders: Artesia Consulting Bruce Horton: Environmental Policy Consulting
Reviewer:	Simon Gordon-Walker: Artesia Consulting

The contents of this document are subject to copyright and all rights are reserved. No part of this document may be reproduced, stored in a retrieval system or transmitted, in any form or by any means electronic, mechanical, photocopying, recording or otherwise, without the prior written consent of the copyright owner. This document has been produced by Artesia Consulting Ltd.

Any enquiries relating to this report should be referred to the authors at the following address:

info@artesia-consulting.co.uk

Telephone: + 44 (0) 1454 320091

Website: www.artesia-consulting.co.uk

Executive summary: delivering long term deep reductions in household water demand

The study considers the potential for making deep reductions in household water consumption and water lost from customer supply pipe leaks, up to 2065.

The need arises from the pressures of increased demand, driven largely by population growth, and the effects of climate change on resource availability. These will have long term impacts on the water sector's ability to deliver services that are resilient and affordable.

We have consulted widely with experts in the UK and abroad, and reviewed research in water and energy efficiency behaviour change, service provision and technology. Future household demands have been estimated through the use of scenarios and modelling of water use in the home. Each view of the future is compared to the current position in the infographic below.

Key conclusions:

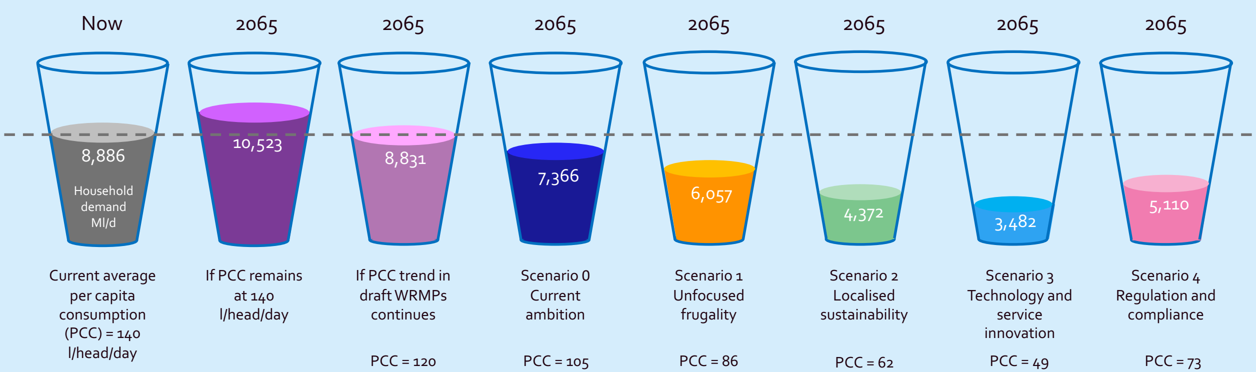
It is possible to achieve average household consumption of between 50 and 70 l/head/day in 50 years without a reduction in the level of utility or quality of water use, but this will not be delivered by the industry working in isolation.

Technologies and services exist now that can deliver these savings if implemented more widely.

Potential costs and implications are outside the scope of this project, and should be addressed in future studies.

Delivering long term deeper demand savings requires greater awareness of water scarcity issues in the UK, combined with greater leadership in moving this whole area forward.

Actions are required now to move beyond 'business as usual' and start to deliver the reductions needed to meet future long term challenges.



First steps to delivering deep reductions in household demand:

1. Strong leadership to ensure that water companies, government, regulators, the supply chain, academia, innovators and others work in a concerted and coordinated way.
2. Monitor progress towards deep reductions in household water demand, and provide support for the ongoing business cases for water efficiency.
3. Meter all domestic properties to facilitate future savings through customer behaviour, utility services, water saving technologies and further research on tariffs.
4. Mandate water labelling for water-consuming products to help consumers select suitably water efficient products.
5. Tackle losses from leaky loos through product standards for new toilets, along with monitoring and fixing of plumbing losses.
6. Develop a strategy to reduce customer supply pipe losses and maintain these assets in the future.
7. Prioritise research into behaviour change for influencing consumer choice of products and changing water use practices.
8. Update planning rules to require new developments to be water efficient, e.g. through community rainwater harvesting and water reuse.
9. Make performance data openly available to encourage and facilitate innovation in services and technologies.

About this report

This report has been produced by Artesia Consulting for Ofwat to examine the long term potential for managing water demand.

The report consists of this main document, and is supported by a number of technical annexes.

Any enquiries about this report should be directed to:

Rob Lawson at Artesia Consulting at the following email: rob@artesia-consulting.co.uk

The primary objective of this project is to understand the long-term potential for demand management in domestic properties in England and Wales. The project will inform Ofwat's long term strategy, including future price reviews. It will also be used to provide insight and expertise to other regulators and government departments on topics such as resilience, infrastructure investment and long-term value for money for water consumers.

Contents

1. Introduction: 1.1. Context

It is widely recognised that pressures from population growth and climate change will reduce the per capita availability of water in the UK generally, and in critical areas, such as South East England, in particular. Demand management has a key role in addressing this challenge.

As a statutory body, Ofwat has to meet all its duties, both primary and secondary, set out in the Water Industry Act 1991. These include:

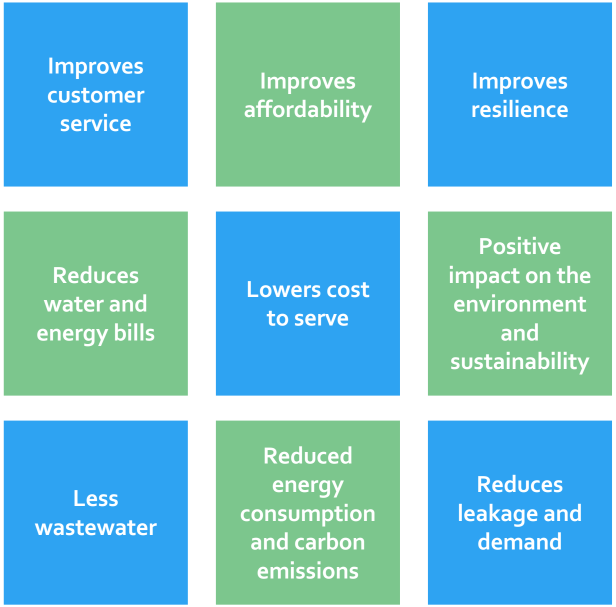
- Protecting the interests of existing and future water consumers, and ensuring affordable bills.
- Securing the long term resilience of water and wastewater systems.
- Ensuring great customer service, and encouraging innovation.

With a rising population, and an expected increase in extreme weather events, companies will face increased challenges to provide water and wastewater services in the future. If households continue with a daily per-capita consumption of around 140 litres, and UK population rises by about 10 million in 50 years, that would add over half a trillion litres a year to supply (approximately a 15% increase in the water taken out of the environment). This population is also forecast to increase disproportionately in the south east of England, where we expect drought events of increasing frequency, duration and severity.

Three key documents have been published recently which highlight the importance of reducing household water demand, and delivering benefits such as those in Figure 1.

The Water UK Long Term Water Resources Planning report (Water UK 2016), demonstrated that there is a significant and growing risk of severe drought impacts in England and Wales. It concluded that, in addition increasing supply, there is a case for considering more extensive measures to manage household demand.

Figure 1: Benefits from delivering water conservation



The report stated that: “the levels of demand management that have been analysed in this report are potentially ambitious and rely on significant behavioural change as well as significant future innovation.”

The Defra (2018) 25 year Environment Plan says that we need to incentivise improved efficiency and less personal consumption, and has asked WaterUK to advise on a PCC target for 2042.

Waterwise (2017) have recently published their strategy for the UK which sets out a blueprint to deliver a vision of a UK in which all people, homes and businesses are water-efficient, and where water is used wisely, every day, everywhere . The strategy sets out an action plan for the next 5 years (2017 to 2022) in 7 areas, shown below:

Waterwise’s strategy actions for the next 5 years:

- Why we need to become more water-efficient in the UK
- Improving water efficiency in our urban environment
- Integrated water management and resilient infrastructure and services
- Water, people and communities
- Products and labelling
- Water company delivery and regulation
- Water efficiency in retail competition

1.Introduction: 1.2. Scope and objectives

The scope of this study is to analyse factors that affect domestic water consumption. For example, customer behaviour, design and use of water-consuming products, use of water meters, and tariffs, and the Internet of Things (IoT). This study has therefore concentrated on the potential to reduce consumption in the home expressed as per-capita consumption (PCC). Note: PCC has been used through out this report to be consistent with historic reported data.

The PCC metric does not include supply pipe leakage nor does it include non-household demand. However, supply pipes are the responsibility of the homeowner, and represent a 'demand' from domestic properties. Therefore part of this study will look at the potential to reduce leakage from customer supply pipes.

The study considers the potential for reducing water consumption in homes and from customer supply pipe leaks over the long term, looking ahead to 2065.

Objective 1: Analyse

How households have used water in the past, and how homes use water today, including a detailed breakdown of the types of use, and considering how usage varies by region, and by property type.

Objective 2: Illustrate

Water company data and forecasts of current and future PCC and types of water use in the home (described as 'micro-components') for 2025-30, and up to 2065.

Objective 3: Propose

The options available to make deep reductions to PCC over the next fifty years. Again, this will include a detailed breakdown of water use, and consider how usage varies by region, and by property type.

Objective 4: Consider

The role of water pricing and tariffs in reducing water use. The potential for current and future technologies to reduce demand, including the potential for automation and analytics to drive behaviour change.

What technology and other interventions have worked well, and less well, in the UK and from international examples and experience.

What we can learn from other sectors; particularly from the experience of the energy sector in promoting energy efficiency and associated behaviour change.

The potential for water efficiency measures to provide wider societal benefits, including energy efficiency

.

Objective 5: Demonstrate

The current leakage from supply pipes.

The potential to reduce this leakage over a fifty year period, and the options for supply pipe leakage reduction.

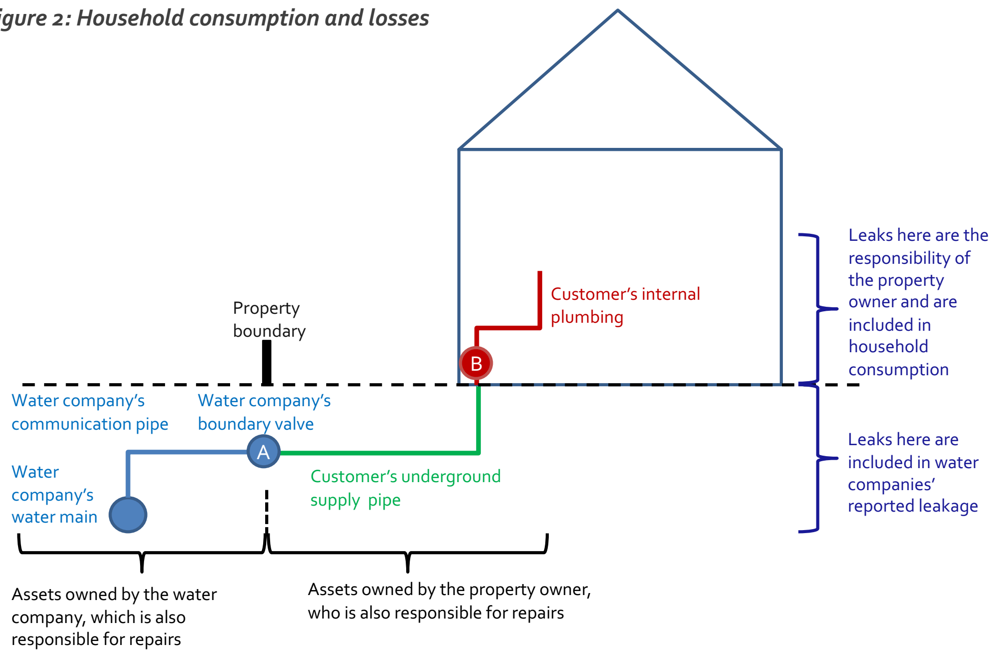
2. Household demand for water: 2.1. Definitions

This report focuses on household water demand and customer supply pipe leakage. This section explains exactly what we mean by these two terms, and how we will report data relating to these two water demands. Referring to Figure 2:

Household water consumption is the water flowing into the property past point 'B'. This includes water consumed, water wasted and losses inside the household or from external taps.

Customer supply pipe leakage includes any losses from the pipe connecting point 'A' and 'B'.

Figure 2: Household consumption and losses



If a household has an external flow meter (at point 'A' in Figure 2) the water flowing through the meter is termed water delivered, and household consumption is calculated by subtracting customer supply pipe leakage from water delivered.

Household consumption can be reported in two ways:

- PHC or per household consumption in litres/property/day
- PCC or per capita consumption in litres/head/day.

PCC is calculated by dividing PHC by the number of occupants in the property. However as individual property occupancy is seldom known, it is more common to sum PHC values to a regional level and divide by the regional population.

PHC varies from house to house and region to region. Variations in consumption can be influenced by: household occupancy, property type, age of occupants, socio-demographic factors (social status, levels of affluence, culture, religion, lifestyles, and household or individual values towards water use), whether households pay via a meter, weather, and the methods used to measure and estimate household consumption (Artesia 2017).

Traditionally, PCC has been used for reporting household consumption, and we use PCC throughout this report to ensure consistency with historic data. Care should be taken when comparing PCC between different regions as there may be variations in household consumption due to the other factors mentioned above in addition to occupancy.

Water companies publish their current and past PCC values on the website: www.discoverwater.co.uk

2. Household demand for water: 2.2. Past consumption

Within this report we are taking a fifty year look into the future of household water consumption. To put this into context it is useful to take a glimpse back in time at how domestic water consumption has changed over the last fifty years.

Figure 3 illustrates the progression of household consumption, in terms of PCC (litres/head/day), since 1960. The data sources are 1960 to 1981 (Herrington 1996), 1992 to 1999 (Ofwat 1999), and from 1999 annual return data has been provided by the Environment Agency.

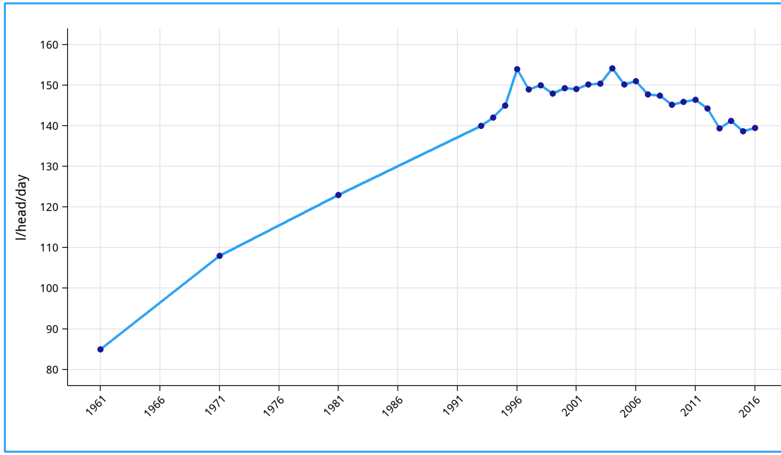
Consumption of water in the 1960s was around 85 l/head/day and has seen a gradual increase over time to just over 155 l/head/day in 2004. Since 2006 there has been a downward trend in overall PCC.

Table 1: Proportions of household end-use consumption

End-use	1976	1991	2003	2015
WC flushing	30%	24%	29%	24%
Clothes washing	11%	15%	13%	12%
Personal Washing	28%	32%	36%	39%
Dish washing	8%	8%	9%	10%
External use	2%	5%	7%	4%
Other internal use	22%	16%	5%	11%

There is no detailed breakdown of household consumption in 1960. However people used less water for personal washing (typically a bath once a week), washed clothes by hand or top-loading washing machines, and washed dishes by hand. We have presented end-use data for 1976 and 1991 (Herrington 1996), 2003 (WRc 2005) and 2015 (UKWIR 2016) in Table 1.

Figure 3: Trend in historic household consumption



The data from 1976 and 1991 is based on customer survey data and assumptions, whereas the data from 2003 and 2015 is based on measurements of the flow of water into households. From this, the amounts of water used for different types of use has been identified. The different sources and methods used to classify the end-uses of household consumption make firm conclusions on trends difficult.

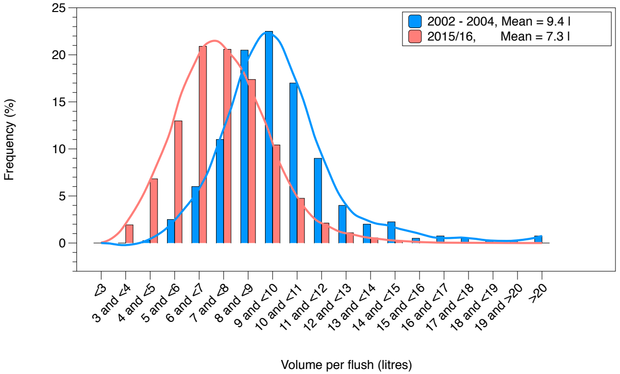
However, there is a consistent increasing trend in the proportion of household water used for personal washing, which is backed up from observations of the transition from a weekly bath to daily showering. A survey in 2013 identified that 70% of the population have a full body wash at least daily, mostly by showering – over 50% never have a bath (Browne et al 2013). Showering used to be considered more water efficient than a bath, and indeed if you take a 5 minute shower with a flow rate of 8 l/min to get clean then this will use about half the amount of a typical bath of 80 litres. However shower times vary greatly, and research into adolescent showering practices (Hassle 2016) indicates that average shower times of 20 minutes are typical in this age group. Taking account of the higher flow rates of power showers, there is clear evidence behind the increase in water used for personal washing.

2. Household demand for water: 2.2. Past consumption (cont.)

There is also good evidence for reductions in water used for flushing WCs over the past 14 or so years, which is due to the successive reduction in WC cistern sizes.

Figure 4 shows histograms of WC volumes per flush for data collected around 2002 to 2004 (WRc 2005) and for data collected around 2015/16 (UKWIR 2016). There are a wide range of flush volumes and this is due to the mix of WC cisterns that exist in homes. The distribution of flush volumes for homes monitored in 2002 to 2004 (shown in blue) and those monitored in 2015/16 (shown in orange) are different. The mean flush volume in 2002 to 2004 was approximately 9.4 litres. This reduces in 2015/16 data to approximately 7.3 litres. This reduction in volume per flush is due to water regulations, which prescribe the maximum flushing volume for the installation of WC cisterns. These currently limit the maximum volume of water flushed to 6 litres; there is no lower limit (WRAS 2005). The current limit was set in 1999, the prior limit was 7.5 litres, and before that 9 litres; older cisterns can have flush volumes in excess of 12 litres. The current water regulations also allow dual flush mechanisms, with flush volumes down to 3 or 4 litres.

Figure 4: Histogram of WC flush volumes 2002 to 2016



The success in water savings due to the reduction in WC cistern sizes has been tempered somewhat by the increase water wasted through leaking WCs. Two studies (Artesia Consulting 2012 and Ricardo 2015) have shown that an increasing number of WCs leak (either through the drop valve in the cistern or the inlet valve in the cistern leaking and then overflowing). These studies present evidence that whilst WCs are leaking, they have an average consumption of between 200 and 400 litres/day. The proportion of installed WCs found to be leaking ranged from 4% to 10%.

Referring back to Figure 3, there is a downward trend in per capita consumption since 2006, equating to about 1.2 l/person/day/year. There have been some key initiatives that have resulted in increased water efficiency activity since 2005. In this year Defra established the Water Savings Group (WSG). The WSG had a leadership role with the overarching goal to reduce the level of PCC.

there has been a downward trend in PCC since 2006, of about 1.2 l/person/day annually

The group existed until the end of 2008. Some of the key outcomes from the WSG were:

- The introduction of annual water efficiency targets by Ofwat for companies in 2010 -15 of 1 l/property/day.
- Establishment of Waterwise to promote water efficiency, support companies in delivering savings, and develop the evidence for water efficiency.
- The introduction of the water stressed area classification for the purpose of extending metering.
- A commitment to improve water efficiency in new homes through changes to Building Regulations and the Code for sustainable homes.

Personal bathing (including showering) is a significant proportion of water use in the home and has increased over time. This presents a challenge for future water conservation.

How can WC cistern volumes be further reduced in the future?

What UK leadership in water efficiency will be required to deliver long term deep savings in household demand?

2. Household demand for water: 2.3. Current consumption

The current demand for water used in households across England and Wales is approximately 8400 Ml/d. This is about 55% of all water put into the supply system.

If all the water produced for household consumption every day was put into water bottles and laid end to end they would circle to the earth about 70 times.

Figure 5 shows the main elements of the water balance; non-household consumption about 20%, total leakage about 22% and 3% other minor components.

Figure 5: Proportions of the water balance

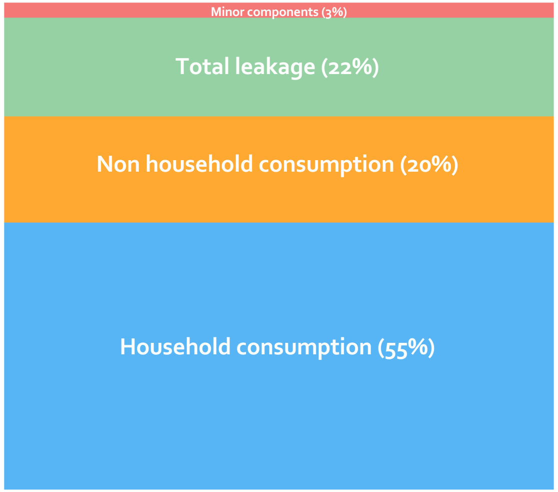


Table 2 shows the average per capita (PCC) and per household (PHC) consumptions in England and Wales, and is also broken down by metered and unmetered properties, and by geographic area (South East, South West, North, and Central).

The data is derived from reported values for 2015/16. The average PCC is illustrated for the regions in Figure 6.

The South East region has the highest household consumption figures, followed by the South West region, with the North and Central regions being lowest. These variations in consumption can be influenced by any of the following: household occupancy, property type, age of occupants, socio-demographic factors, whether households pay via a meter, weather, and the methods used to measure and estimate household consumption.

Figure 6: Geographic mean household consumption as PCC (l/head/day) values for 2015/16

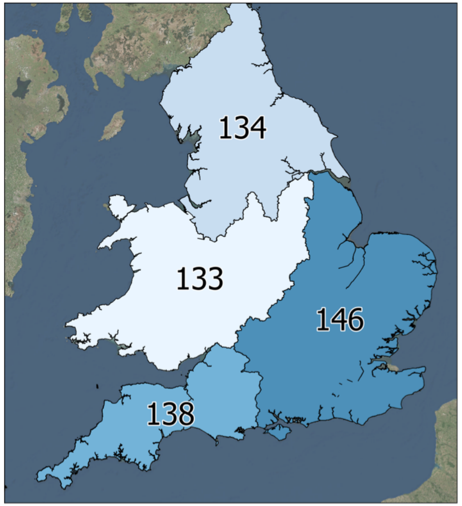


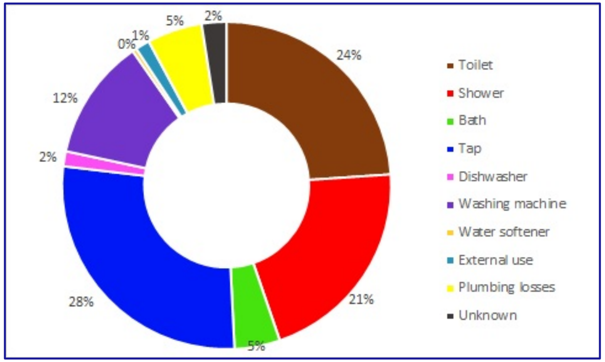
Table 2: PCC and PHC for different geographic areas in England and Wales

Geographic area	Per capita consumption (l/head/day)			Per household consumption (l/property/day)		
	All households	Unmetered households	Metered households	All households	Unmetered households	Metered households
England and Wales	140	142	120	342	379	266
South East	146	160	132	373	460	305
South West	138	159	123	311	426	246
Central	133	142	117	318	364	250
North	134	147	111	316	371	237

2. Household demand for water: 2.3. Current consumption (cont.)

We can break down household consumption into the types (or 'micro-components') of water use in the home. Figure 7 shows the average breakdown of micro-components for a group of 62 metered properties, spread across England and Wales, monitored in 2015/16 (UKWIR 2016).

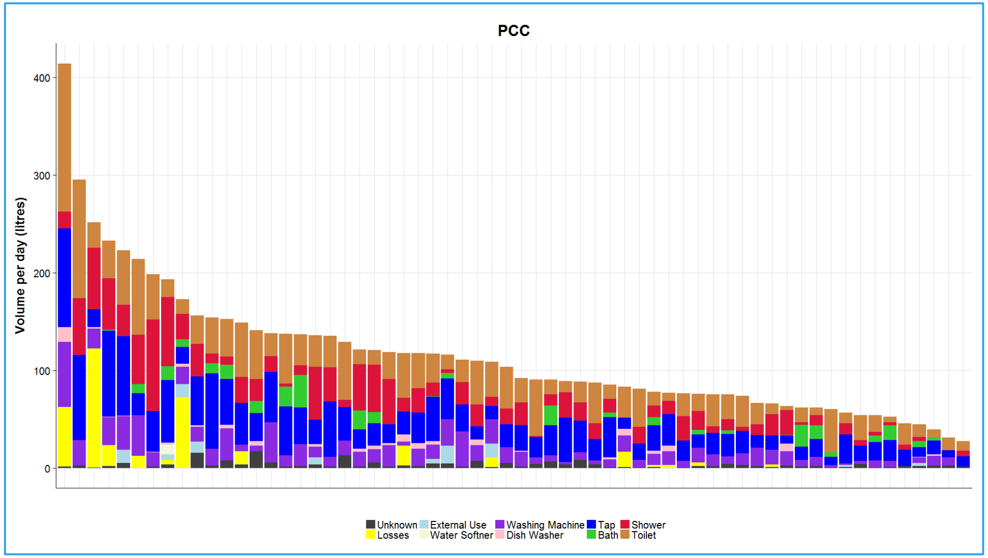
Figure 7: Average micro-components of water use



The average values in Figure 7 mask a complexity of different water uses in each property, shown in Figure 8. This figure shows that the range of per capita consumption (PCC) values from about 420 to 40 l/head/day.

This starts to illustrate the variety of use in individual properties due to the factors discussed earlier in this section.

Figure 8: Micro-components of water use for each property



Some properties have leaks; whilst shower, bath, clothes washing, dish washing and other water uses vary between properties with similar PHCs and occupancies. Academic studies into the behaviours and practices of water use in the home report similar findings.

A study into the patterns of water use (Browne et al 2013), highlighted substantial diversity between homes in terms of the way in which the occupants performed different practices (personal hygiene, laundry, kitchen and garden watering practices).

The variation in water use between homes is important when we think about how to deliver deep reductions in household consumption.

The range of behaviours, habits and practices of water use, our attitudes and values towards water use, and the type of house, its water fittings, and the garden are all important factors to consider when trying to reduce water consumption in the future.

2. Household demand for water: 2.4. Effect from metering

Another important factor influencing water consumption in the home is whether a household pays for water via a metered bill.

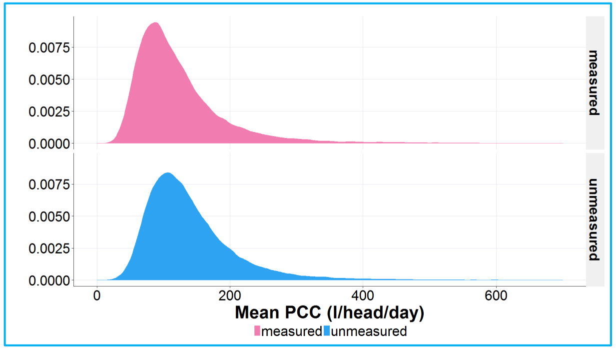
Table 2 (presented earlier) indicates that average household consumption for metered households in England and Wales is 266 l/property/day, compared to 379 l/property/day in an unmetered home. In terms of PCC the values are 120 and 142 l/person/day respectively.

There are various ways that homes become metered: all homes built since 1990 are metered, unmetered customers can choose to become metered, and water companies can meter existing properties if they are in a region of water stress and metering helps balance supply and demand.

Households that have chosen to have a meter tend to opt in order to save money on their water bill, largely because they have lower than average occupancies and/or consumption.

Metered households also have fewer losses and include fewer very high consumption properties. This is shown in Figure 9, which illustrates the distribution of consumption in a sample of metered (pink) and unmetered (blue) properties from the same region. There is a lower average PCC and a shorter right hand tail on the distribution plot for the metered households.

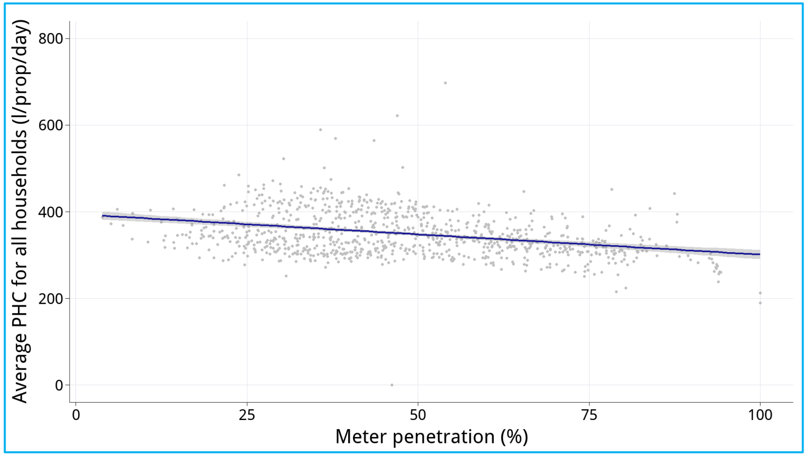
Figure 9: Distributions of metered and unmetered consumption



Recently Southern, South East, Thames and Affinity Water have implemented compulsory or progressive meter programmes. A recent publication (Ornaghi and Tonin 2017) on the impact of Southern Water's programme to meter the majority of homes in their area indicates a 16.5% reduction in household consumption in metered homes.

If we look back at all the annual reported data from water companies from 1999 to 2016 and plot the mean household consumption for all properties against meter penetration, rather than time, then there is a significant downward trend (shown in Figure 10).

Figure 10: Household consumption against meter penetration for water companies in England from 1999 to 2016



This indicates that regardless of all the other influencing factors, increasing the proportion of households on a meter will reduce the mean consumption through a range of factors, including:

- Customers changing their behaviour to use less water or install water efficient devices.
- Consumption is being measured in the majority of households rather than being estimated.
- Losses being identified and repaired.

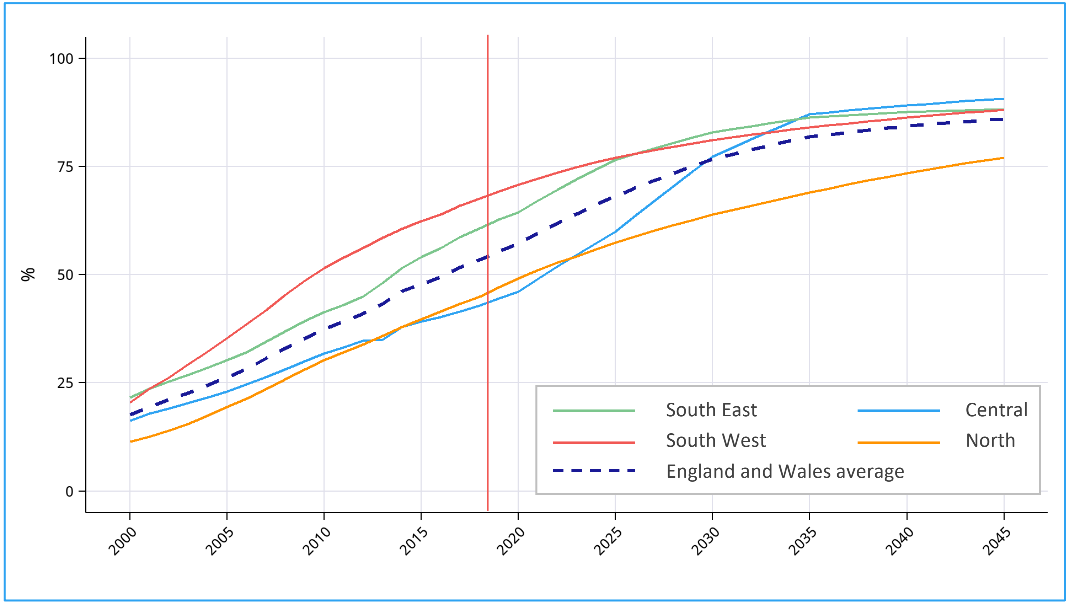
2. Household demand for water: 2.5. Metering and tariffs

Figure 11 shows the progression of metering since 1999 for each water company, and the projected metering rates from the current draft water resource management plans. This illustrates that for some areas a significant proportion of homes will still pay for water use from an unmetered bill by the end of 2045. Table 3 shows the proportion of properties metered in each area by 2045.

Table 3: % of homes metered by area in 2045

Area	% of homes metered
England & Wales	86%
South East	88%
South West	88%
Central	91%
North	77%

Figure 11: Progression of metering since 2000



For areas where meter penetration is high, the use of tariffs provides a potential tool for managing demand in households. Theory suggests that that there is a price elasticity for demand (metered users will limit their use as price increases). It is generally assumed that the 'price elasticity of demand' is low (generally well below 0.5) for water (UKWIR, 2013; Komives et al, 2005), meaning that demand will fall by less than 0.5% for every 1% increase in price.

There are broadly two types of water tariff that are discussed in the literature for demand management, and these are: rising block, and seasonal. The rising block tariff works by charging more when the cumulative volume consumed exceeds a threshold. Seasonal tariffs impose an increase in tariff during specific periods (e.g. between defined dates, periods when demand is high, or any other period).

The literature suggests that there are four key aspects that any demand management tariff needs to deliver: the tariff should be fair, it should not be overly complex to understand or implement, it should take account of household size i.e. occupancy (so that high occupancy households are not disadvantaged), and the tariff should provide feedback to customers on their water consumption in order for them to make an informed change of behaviour.

There is evidence (Clayton, 2010) for much greater variation in elasticity, with estimates between 2.5 and 4.5 times higher in summer, and up to 4 times greater amongst highest income groups. This suggests that the potential for variable tariffs to influence demand could be very significant among some consumer groups and during periods of high demand.

Further research should be carried out to investigate how customers would respond to more sophisticated tariffs and what mechanisms can be used to provide tariff feedback to customers

2. Household demand for water: 2.6. Trends and current forecasts

Figure 12 and Figure 13 show the past and future trends in household water consumption. Figure 12 has been derived from annual return data provided to the Environment Agency by the water companies, and Figure 13 has been derived from the water companies' published draft water resource management plans.

Note that the data in Figure 11 is annual reported data and is therefore influenced by weather variations. The future trends present Dry Year annual average PCC values (the consumption expected in a dry year, therefore there are no annual weather variations).

Table 4 shows the average trends in PCC for the past 10 years, the next 10, 20 and 30 years. These trends are a result of a number of factors including: increased metering, water efficiency practices, purchasing water efficient devices and other external influences.

It is interesting to note that the rate of PCC reduction over the last 10 years (2005-2015) is similar in the South East , North and South West regions, despite the greater focus on implementing demand reduction measures to balance supply and demand in the South East regions. This may mean that there is a greater upward pressure on PCC in the South East that is dampening the additional demand reduction measures.

Going forward the predicted rate of PCC reductions over the next 10 years is greater than the following 20 years. The South East has the greatest reduction in PCC over the next 10 years, levelling off in the last 10 years. The North region sees the greatest reduction in PCC up to 2045.

If the average demand reduction forecast for the next 10 years is maintained to 2065, the PCC in 2065 would be about 105 litres/head/day.

Table 4: Historic trends and current forecasts by area - annual average trend in PCC (l/head/day)

Region	2005 - 2015	2015 - 2025	2025 - 2035	2035 - 2045
England and Wales:	-1.1	-1.2	-0.64	-0.21
South East:	-1.13	-1.37	-0.69	-0.14
South West:	-1.27	-0.88	-0.40	-0.34
Central:	-0.93	-0.82	-0.63	0
North:	-1.15	-1.13	-0.63	-0.49

Figure 12: Past trends in PCC by region (reported values)

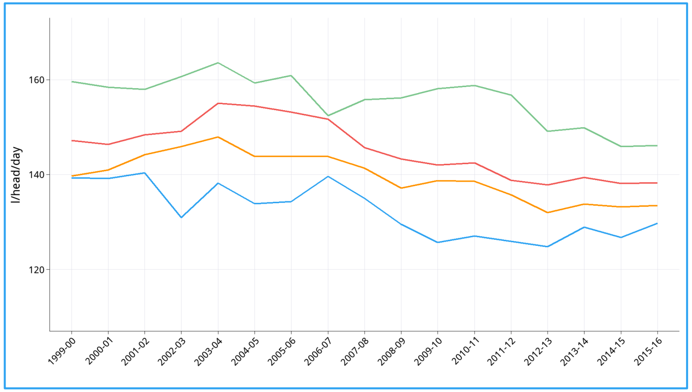
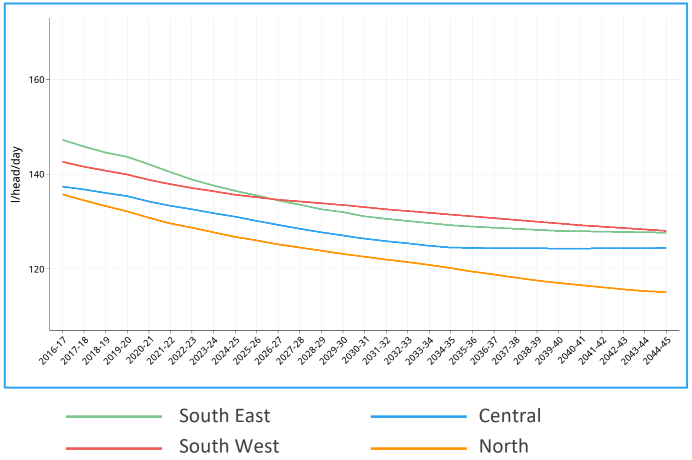


Figure 13: Future PCC forecasts by region (DYAA values)



3. Supply pipe leakage: 3.1. Current and future trends

Customer supply pipe leakage (CSPL) is defined in Section 2.1. and illustrated in Figure 2. It presents a complex challenge for water companies, in that the asset is the responsibility of the property owner, but any leakage from the customer's supply pipe is reported in the water company's total leakage figures. When it comes to repairing a leak on a customer supply pipe, it is the property owner's responsibility to do the repair.

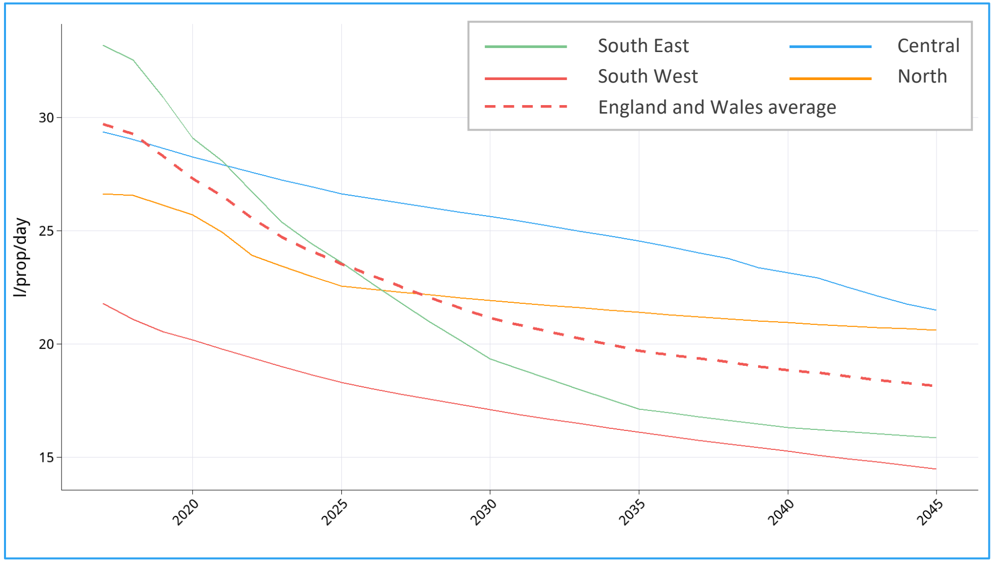
Customers are often unaware that they have responsibility for the customer supply pipe, and repairs or replacement of the asset can be complicated by needing to access and work within a customer's property, with potentially expensive reinstatement costs.

In 2013/14 Defra consulted on the ownership of customer supply pipes, and whether they should be brought under the control of water companies in a similar way to private sewers. The consultation concluded that whilst there were benefits to be gained from transferring ownership of private supply pipes to water supply companies; 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.

During the consultation there was a significant amount of research carried out by both water companies (through UKWIR 2009, UWKIR 2014), and Government on the impacts on customers, the costs and benefits of customer supply pipe leakage. UKWIR has continued to carry out research in this area to look at the economic levels of customer supply pipe leakage (UKWIR 2015).

Figure 14 shows the levels of CSPL derived from the draft water resource management plans.

Figure 14: Customer supply pipe leakage trends



Currently, the average customer supply pipe losses are about 30 l/prop/day (about 8% of household consumption), and are projected to reduce to 18 l/prop/day in 2045. CSPL currently accounts for 22% of total leakage, interestingly this rises to 26% of total leakage by 2045 (due to forecast reductions in distribution leakage).

Thames Water propose the biggest reduction in CSPL (the purple line in Figure 14 from 53 to 17 l/prop/day), through installing smart meters and using these to target smaller customer supply pipe leaks.

3. Supply pipe leakage: 3.2. Challenges and issues

The length of customer supply pipe is not accurately known, however using an estimated length per property of 9m (UKWIR 2009), and assuming about 25 million homes in the UK, there are approximately 225,000 km of customer supply pipe in England and Wales. This compares to about 340,000 km of water mains in England and Wales.

Neither is the material that they are made from accurately known, this is normally assumed from the age of the property and the material used at the time of construction (UKWIR 2009).

Generally there is poor information on the condition of the customer supply pipe assets. Yet they make up almost 40% of the total network and account for 22% of total leakage. At the present time there is no long term strategy for managing and maintaining these assets.

We gathered views from a number of stakeholders on the challenges around customer supply pipe leaks that companies face today. There was a general concern about ownership, identification, reinstatement costs and implications for SIM (Service Incentive Mechanism) measures.

Customer supply pipe leaks are found either by sounding on the stop tap to listen for a leak or by investigation of high anomalous meter reads.

For unmetered customers sounding is the only option, this means that small, but significant leaks could be running for months, or even years, without detection. For metered customers the frequency that the meter is read for billing purposes affects the length of time a leak can be running. With new smart meters being installed the length of time for a leak to be identified should be reduced significantly.

Most companies offer either a subsidised or free repair/ replacement to customers with a supply pipe leak (UKWIR 2014) as part of their overall leakage strategy. Several of the stakeholders we talked to stated that the repair of the supply pipe is not that costly, but it is the reinstatement of the customers land that has a significant cost. This is due to the wide variety and expense of the surfaces that customer supply pipes lie under from brickwork drive ways to landscaped gardens. This makes the management and costs of resolving customer supply pipe leaks much harder than the rest of the network. When these costly reinstatements are not carried out this causes issues with customer satisfaction, which impacts on SIM metrics.

Certain companies have had success by not offering a supply pipe repair for free, but support the customer through the process with a designated team. This has helped them improve their SIM score, and also helped to reduce customer supply pipe leakage.

It is clear from Figure 14, that supply pipe leakage on the most part will only reduce marginally for the majority of companies.

The lack of understanding around ownership of customer supply pipes, with only 44% of households knowing it was their responsibility to fix a CSPL (UKWIR 2014), makes it a challenge to reduce this area of water demand in households. The challenges increase when there is shared ownership of a supply pipe between a number of customers. A change in ownership of these pipes to water companies may help remove this as companies would be more willing to invest in proactive replacement strategies as they do for the rest of the network.

Smart metering and customer engagement technologies that inform the customer and the water company that their supply pipe may be leaking have the potential to reduce CSPL to around 8 l/prop/day in the future.

The cost of reinstatement and the confusion over ownership will mean that deep reductions in CSPL are probably prohibitively expensive in the next 15 years. However with new technologies that reduce awareness times and allow for easier repairs, large reductions are possible in this area by 2065.

Annex A has further information on supply pipe losses.

4. Research: 4.1. Future views from stakeholder research Q1

We gathered views from a range of key stakeholders who were likely to have views on long term deep reductions in household water demand. These included water efficiency champions in water companies, consumer organisations, regulators, academics, consultancies, and new service providers. We received 25 responses to the survey and followed up on a number of these through semi-structured interviews.. We asked for feedback on four key questions:

- *What level of consumption could be achieved in 50 years' time?*
- *What would be your overall vision for making deep reductions in household consumption in the next 50 years?*
- *What 'enablers' (which might be legislative, regulatory, policy, technical or behaviour related) would be need to deliver this?*
- *What do you think are the barriers to achieving this?*

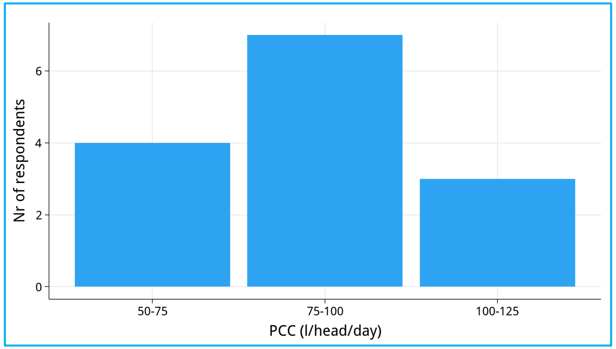
What level of consumption could be achieved in 50 years' time?

Whilst several respondents found this is a difficult question to answer (given the timescale horizon envisaged), the majority of respondents who chose to answer indicated that it would be possible to reduce consumption to below 90 litres per head per day within fifty years. Figure 15 shows a histogram of the responses.

Some suggested an interim (25-year) target of around 100 l/h/d; then a more radical target of 75-80 l/h/d over the longer term. The aspiration cut across all stakeholders that this should be possible with legislative and technical solutions. With significant cross stakeholder agreement, such an aspiration should be starting to develop on the basis of 'common ground'.

Some respondents mentioned the importance of not going too low (towards 50 for instance); where health and quality might then be compromised.

Figure 15: PCC aspirations in 50 years time



"I believe we could achieve around 50 litres per day. I currently use around 70 litres a day without doing anything too out of the ordinary and feel this could be reduced."

"85 l/head/day can be easily achieved in houses with meters and water recycling for toilet flushing."

"So I would say that the fifty year challenge is to get most people to use a little bit less through pretty rudimentary behaviour change and water efficiency technology, and the key bit is to get those fewer large users to use a lot less."

"Whilst PCC is useful in its place, I am not sure that it should be the focus of a 50 year ambition. Something around the quantity of water abstracted from the environment may be better placed to drive innovation and take-up of new technologies."

"80-100 litres per person per day and we may not have a choice in 50 years' time if current water quality/availability and energy trends continue."

"South Africa's 50 litre challenge in Cape Town suggests that it would be difficult to get to that without serious implications for quality of life."

"our family of four use 70 litres PCC and by no means are we water martyrs despite my best intentions - there are daily showers and kids occasionally leaving taps on!"

"We could aim for 80 l/head/d as long as the technology enables us to achieve this without having a negative impact on quality of life. It would probably involve some degree of retro-fitting on existing properties and improved water recycling/re-use technology."

4. Research: 4.1. Future views from stakeholder research Q2

What would be your overall vision for making deep reductions in household consumption in the next 50 years?

There is general support for a fundamental change in social attitudes to water and for the positive contribution that changing regulation and legislation can make. One respondent (supported by the majority) was adamant that the "number one thing" to instigate is a mandatory labelling system to drive the availability of water efficient products and their use.

Respondents overwhelmingly identified the need for a sustained long term national campaign to increase awareness of water in the environment and the need for water efficiency. One respondent mentioned the need for a concerted effort of 'myth-busting' at a national scale ("always raining", "we get lots of rain", "it should be a free resource").

This vision of a national campaign is wider than water companies and other groups were cited to incorporate that awareness to builders, developers, innovators, designers and architects.

Technology is mentioned for reducing water consumption directly, replacing mains water with locally recycled water, or for enabling behaviour change. Smart metering was discussed in this latter context for being able to identify excessive use or wastage, and relay this information back to the utility or the consumer.

Some mention was made of "water neutrality" (which was in vogue 8 to 10 years ago) in order to offset new consumption in growth areas.

"I would like to see water efficiency valued as an environmental behaviour in the same way as recycling is now."

"We need a 'plastics' moment so that the penny drops and people understand the value of water ."

"Focus on wastage – engineer as much unnecessary use out of the system as possible."

"Stop water companies being the main point of contact for customers with regards water efficiency – there is a conflict of interest between revenue and water efficiency."

"The step change is really targeting those high users - both in terms of waste, high volume use, especially in the dry year."

"it's also really clear that people are more receptive to behaviour change when they can understand why"

"Have someone like David Attenborough support the cause."

"We believe we need a joint societal effort and partnership approach with key stakeholders such as government, regulators and community partners."

"Myth busting is required as a national scale ("always raining, we get lots of rain, it should be a free resource, all responsibility should be with water companies")."

"It will be imperative that customers have access to real-time consumption information and bespoke advice and tools to help them manage demand."

"new innovative technology needs to be drastic and/or revolutionary."

4. Research: 4.1. Future views from stakeholder research Q3

What 'enablers' (which might be legislative, regulatory, policy, technical or behaviour related) would be need to deliver this?

The respondents gave significant emphasis on the need for increasing legislative and regulatory reform as important enablers to back up a sustained national campaign. In particular three quarters of respondents mentioned the implementation of a mandatory water efficiency labelling scheme, and concentrated on the importance of improving and delivery water efficient products…there should be no toilets leaking!

Alongside this there were many who advocated the importance of tighter building and planning control around new developments and ensuring all homes are water efficient - with all retrofits to be to a specified standard; building regulations and water appliances, fittings need to meet minimum standards.

A number of important enablers were mentioned for reducing consumption in existing households; for example water companies increasing meter penetration - a progressive metering approach will win customer support rather than overwhelming compulsory metering. Smart metering is a must for the future and the water industry could learn lessons from the energy smart meter at roll-out.

"New building standards from CLG, mandatory water labelling from DEFRA, behavioural incentives from cabinet office, white paper on water efficiency and abstraction reform."

"Increased confidence that demand management measures proposed by water companies including metering and smart metering will be accepted by Ofwat"

"Replace every single flush toilet by 2030. Replace all single flush in business properties, and sensor controls in all urinals"

"Mandatory water labelling. This could be the single-most powerful tool to reduce PCC with time. Remove drop-valve WCs from market to eliminate leaking WCs."

"Metering essential. Meters that can send data about high volume continuous use to companies so that they can target response."

"Whilst the introduction of dual-flush WCs into Fittings Regs has delivered a significant net water saving, the increasing volumes of mechanical drop-valve cisterns is creating a new and growing water loss problem."

"…unless customers are engaged and understand why they need to reduce their water use, the other enablers are not likely to help to achieve the objective of reducing PCC."

"Consideration of the forward price of water, based on future scarcity would help drive change."

"Metering every property is fundamental. We can find more leaks/wastage and undertake greater water efficiency on metered households. "

"if technology can allow clothes washing, dishwashing, toilet flushing, etc. to be done with less water, then consumption can be reduced without the difficulty of changing behaviour."

"Variable charging by meter (advocate a quite large first block and then a second block to target profligate use)."

"Hot water use is the second largest part of domestic energy use and carbon emissions, but the UK's energy efficiency programmes do not actively include/require water efficiency delivery. This is a massive lost opportunity to save water and further reduce energy use/carbon emissions."

4. Research: 4.1. Future views from stakeholder research Q4

What do you think are the barriers to achieving this?

The respondents identified two main barriers - people's lack of interest in water (unless there is a drought) and Government reluctance to legislate or regulate in the area of building regulations and water labelling. There is scepticism that voluntary schemes would have any significant impact; which is in contrast to energy efficiency labelling.

Two aspects of water company regulation were presented as potential barriers - first is a mind-set brought about by regulation in that a call for water use restraint is perceived as a water supply 'failure' and fear penalisation from Ofwat - this hampers honesty and candid transparent communication with customers.

Secondly, levels of leakage (mentioned by 4 respondents) provide a barrier of attitude to water companies – "why should we save water when the companies waste so much?"

Some respondents argue that the price review framework which incentivises water companies to compete against each other on PCC is not conducive to joint working and sharing of evidence or campaigns.

Other barriers identified include: lack of a national holistic long term thinking, fragmented responsibilities, short termism, and the lack of widespread collaborative solutions beyond the water companies.

"Willingness and fully engaged Government/regulatory/community partners is vital for deep reduction in household consumption."

"Market reform - not being able to liaise with business users around reduction in water use and retailers currently not doing very much with water efficiency."

"Demand management activities often have 'uncertain' outcomes, making them far less appealing to water companies. Much simpler to look for a 'new' supply."

"Customers' valid question is 'why should we save water when the companies waste so much?' Companies need to show they are tackling it"

"People do not seem to connect the dots between the environment, climate change, population growth and their water use."

"In recent years water efficiency messaging has tended to happen at times of drought/pressure rather than having been a continuous activity. As a result, people forget and quickly go back to their 'old' ways. Water is relatively cheap compared to other utilities."

"Cost is always a barrier to any measures but the WRMPs mostly rely on demand management over the early years of their plans to meet deficits, because it is cheaper."

"Keeping water label as voluntary would mean little/no impact – barrier would be Government not wishing to regulate. Similar for Water Fittings Regulations – no change will mean drop valve toilets continue to be installed ensuring the problem exists long into the future."

"The way that companies perceive that appealing to customers for restraint in dry periods is akin to admitting failure."

"It is difficult in the UK to walk into a home improvement store and get any information about which shower head is more efficient. How can we expect people to save water if they don't have this information?"

4. Research: 4.2. Future measures for reducing household water demand

We researched a number of sources for information on future measures for deep reductions in household water demand, these included:

- water company draft Water Resources Management Plans,
- academic papers,
- a consideration of relevant behavioural economics approaches,
- on-line searches for new technologies, approaches and systems, Patent databases, and
- a review of approaches to efficiency in other sectors, particularly energy.

From this survey we identified approximately 80 different measures. These are detailed in Annex B. The measures were grouped into 7 response categories based on whether they:

- Affect consumer choice in water using practices
- Deliver greater efficiency
- Change public perceptions about water
- Affect consumer choice in purchasing decisions
- Affect the governance, funding or regulation of water service providers
- Affect resource provision
- Reduce water wastage

Examples of the measures included in the 7 response categories are shown in Table 5.

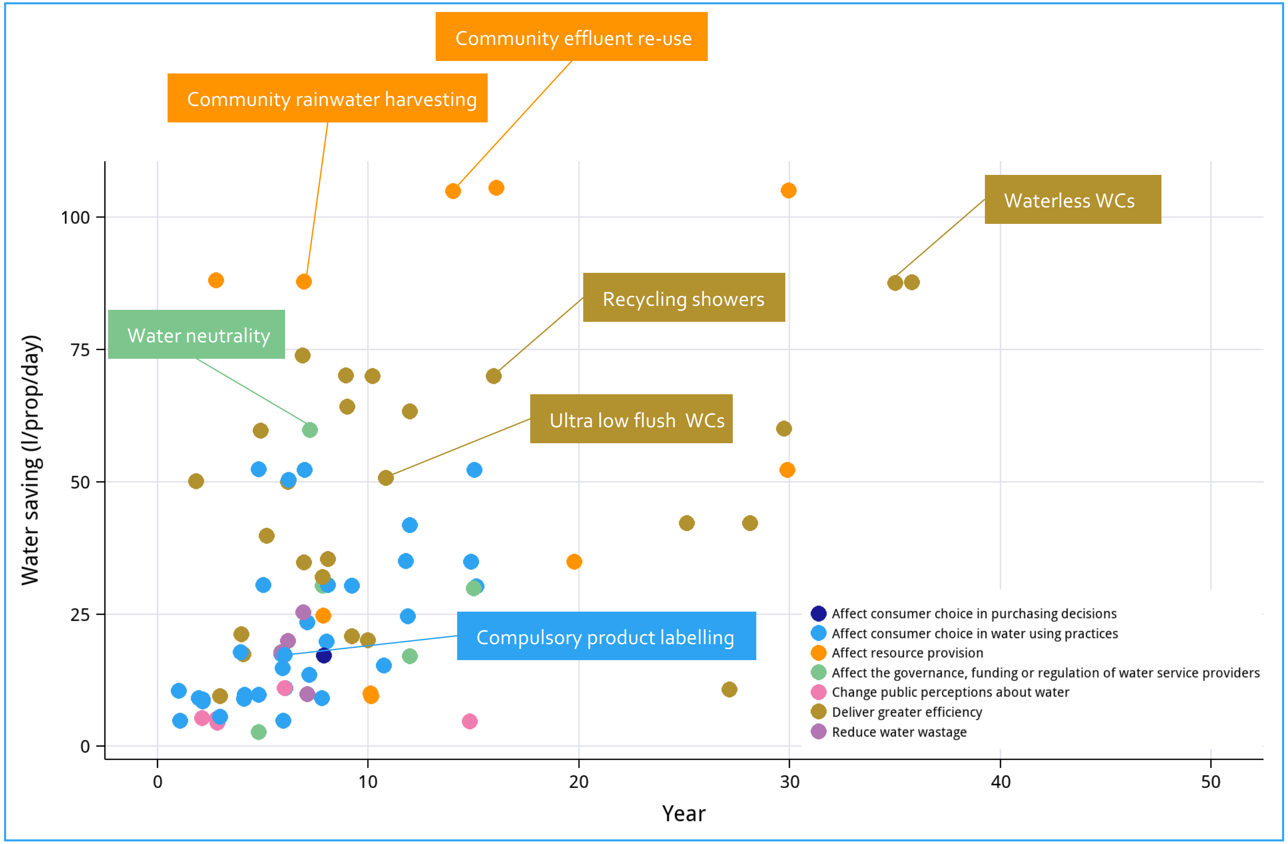
Table 5: Examples of water demand reduction measures by response category

Response category	Examples of measures
Affect consumer choice in water using practices	Smart metering, tariffs, pay-per-use appliances, linking energy and water efficiency
Deliver greater efficiency	Ultra low flush toilets, recycling showers, waterless washing machines
Change public perceptions about water	Incentives, home water reports, smart bills, social norms and feedback
Affect consumer choice in purchasing decisions	Compulsory water labelling, rebates, scrappage schemes
Affect the governance, funding or regulation of water service providers	Water neutrality, supply pipe ownership, natural capital accounting, utility bundling
Affect resource provision	Community rainwater harvesting, Reduce amount of water available for public water supply
Reduce water wastage	Fix leaky loos, ban sale of drop valve toilets, leak detectors, smart taps, smart showers

The measures were then scored based on an estimate of how many years until they could deliver widespread benefits (even if they exist as a measure now), and the level of potential water saving (which is derived from evidence bases and published data. The results are plotted in Figure 16 (on the next page), highlighting some example measures.

4. Research: 4.2. Future measures for reducing household water demand (cont.)

Figure 16: Chart showing the measures for reductions in household water demand and potential impact in terms of water saving and time to widespread delivery



The demand reduction measures were scored based on an estimate of how many years until they could deliver widespread benefits (even if they exist as a measure now), and the level of potential water saving (which is derived from evidence bases and published data).

The results are plotted in Figure 16. This figure plots all of the measures (colour coded by response category) and then highlights some example measures.

A majority of the measures in the bottom left hand corner of the plot will contain measures that are in the current draft water resources management plans as options for reducing demand. Measures delivering deep demand reductions are towards the top of the figure.

Measures to the right hand side of the graph would require clear leadership, partnering with a wide range of stakeholders, and support for the ongoing business cases for water efficiency

Examples of measures that the potential to deliver deep reductions in household water demand that exist now, are shown on the next page. Some of these exist as trial products or sites, and some are fully functioning commercial products or solutions. Further details on these measures area in Annex B.

4. Research: 4.3. Examples of measures for reducing domestic water demand

Introduction

This page presents 14 examples of potential deep demand reduction measures identified from our research. Each example is either in progress at the moment, or could be rolled-out more widely in the UK in the next 10-15 years.

Propelair© ultra low flush toilet

This toilet uses displaced air and water to provide a high-performance flush using only 1.5 litres of water per flush. It is currently aimed at commercial use but reduced noise and cost would make it viable for domestic use.

Albion Water - Rissington

Albion Water is providing full water and wastewater services to this ex-RAF base, including 370 existing homes and 368 new properties. Recycled water (green water) from wastewater is part of the scheme for new homes, for toilet use and garden watering.

Thames Water: Smarter home visits (SHVs)

The visits include tailored retrofits and advice to households, based on analysis of water use using a bespoke app. SHVs are also provided alongside the company's ongoing smart meter rollout.

North West Cambridge Development

A community-wide rainwater harvesting (RWH) system to provide non-potable supply for toilets and washing machines for around 3,000 new properties. RWH is included in the development to meet planning conditions.

Miele 'bundles' subscription

The manufacturer Miele offers a service plan for washing machines and dishwashers in the Netherlands which include flat monthly fee or pay-per-use option with a lower monthly fee and a cost per use, with online functionality (i.e. smart devices).

EnergieSprong refurbishments

Energiesprong is a Dutch company which delivers a 'wrap-around' retrofit of houses with the aim of delivering net-zero energy refurbishments in the UK. The focus is on thermal insulation but hot water efficiency could be readily incorporated.

Smart showers

Showers are available which can be programmed to personal use patterns, e.g. to save water whilst 'soaping-up', and which have proximity sensors and timers – e.g. Aqualisa. The Amphiro device connects to existing showers to provide water and energy use data.

Mandatory water labels

The Australian Water Efficiency Labelling Scheme (WELS) requires point of sale labelling for a wide range water using products. It is estimated a total of 70 billion litres per annum in water savings have been achieved from 2006, when the scheme began, to 2013.

Green Redeem customer rewards

Water companies are working with Green Redeem to provide customers with additional incentives to save water. Points earnt can be spent by customers or put to community projects.

Southern Water: Target 100

The aim of the Target 100 strategy is to reduce average consumption to 100 litres per person per day by 2040. The four pillars of the strategy are: smart meters, home visits, personalised customer contact and incentives such as Green Redeem.

Watersmart

Watersmart makes use of customer meter and other data to provide personalised bills and behavioural nudges (e.g. comparing use to local average). Leak alarms can be provided alongside customised advice for reducing water use.

Anglian Water: The Smarter Drop

A focused water efficiency programme including advertising, education and other 'outreach' work, plus installation of smart meters, aiming to achieve average consumption of 80 l/person/day in Newmarket.

Recycling showers

Systems are on the market which collect and purify water that would otherwise run to waste from domestic showers. The Orbital Systems shower claims to recycle up to 90% of the water used. Prices are currently very high but would decrease with market uptake.

The waterless toilet

Currently the highest profile example, developed at Cranfield University for use in less developed countries, uses nano-membranes to extract water from solid waste and then gasifies solid waste. No power or water is required.

5. Scenarios: 5.1. Introduction and scenario creation

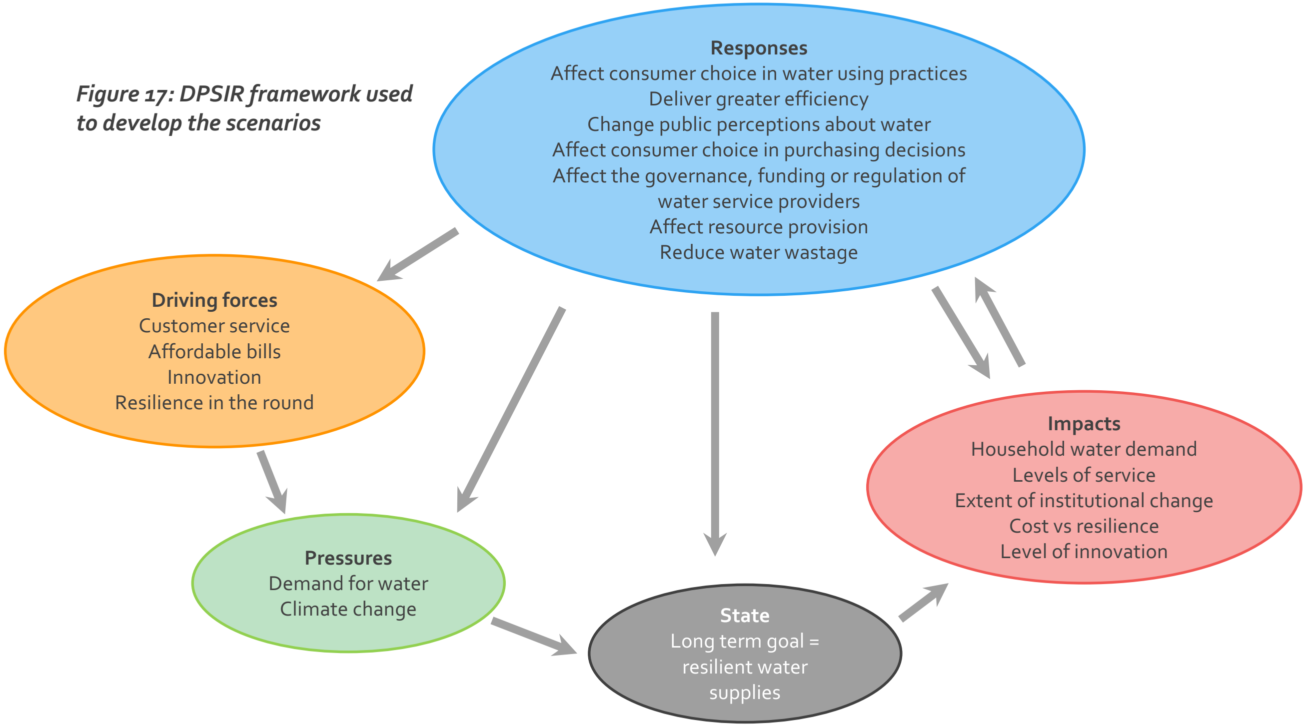
The research conducted in this project illustrates the complex links between stakeholders and activities associated with water demand and demand management. This complexity presents challenges for predicting the level of household water demand reductions that might be achieved in 50 years time. Therefore we have developed five scenarios to reflect the impact from a range of drivers and pressures. The scenarios have been developed using a DPSIR framework (Shikun Sun, et al 2016). The development of the DPSIR framework is described in Annex C, and is summarised in Figure 17.

We assume the following are constant across all scenarios:

- Population and demographic forecasts
- The effect of climate change on water resource availability and demand
- Macro-economic conditions
- Levels of household metering.

Five different scenarios have been developed, each resulting in a different level of ambition in terms of PCC reduction in 50 years time. The scenarios provide a range of uncertainties and risks, and help identify opportunities for resilient responses.

Figure 17: DPSIR framework used to develop the scenarios



5. Scenarios: 5.2. Descriptions of each scenario

The five scenarios are described in each of the boxes. Scenario zero, current ambition, sets a baseline that starts with the current ambition of water companies for the period up to 2025, and then gradually reduces the rate of PCC reduction over the following decades up to 2065. The other four scenarios deliver deeper reductions in PCC over the next 50 years. The next few pages describe how the reductions in PCC have been modelled.

S-0. Current ambition

There is progress regarding public awareness of future water scarcity issues (via planning control) and there is also reasonable progress to increase the efficiency of water using devices and deliver behaviour change via increased metering, voluntary water labels, and stricter product regulation.

S-1. Unfocused frugality

The public do not perceive water scarcity as a problem and there is limited regulatory intervention or organisational innovation to limit resource availability or constrain water use. Technology fails to deliver efficiency or reduce wastage and as a result households need to conserve water.

S-2. Localised sustainability

Water scarcity is widely recognised as an important issue. Markets in water resources and water services results in widespread competition and local providers delivering integrated water services. This positively influences consumer behaviour in purchasing and use of water using devices.

S-3. Technology and service innovation

Market-driven high-tech solutions drive very high levels of water efficiency and reduces water wastage, e.g. through home automation and waterless fixtures and fittings. A new focus blurs the lines between regulated utilities and home services, including smarter tariffs and pay-per-use.

S-4. Regulation and compliance

Water service providers do not adapt to water scarcity, despite increased public awareness of the issue. Regulators apply strict controls on water availability and usage via punitive controls for companies. Variable tariffs and other behavioural measures are used to limit water use.

5. Scenarios: 5.3. Water use in the home – looking back and forwards 50 years

Before modelling the reductions in PCC for each scenario, it is useful to look back at how water use in and around the home has evolved over the last 50 years, and how it might evolve over the next 50 years. This is illustrated below, where the different water uses have been colour coded as technology (in blue) or behaviour (in green), past in dark text and future in light text.

Water use in the home	1968 -50 years	1993 -25 years	2018 Now	2043 +25 years	2068 +50 years
WC flushing	> 12 l/flush Inside & outside WCs Night water, chamber pots	7.5 l/flush multiple inside WCs Flush everything	Dual 6/4 l/flush Flush only wee & poo	< 4 l Lower flush WCs Replace with rain or grey water flush	Ultra low flush WCs Zero water WCs
Personal bathing	1 bath/week, washing only Flannel wash, teeth clean once/day Few showers	Central heating/hot water systems Increasing importance of personal hygiene Showering/bathing to relax	Transition to 1 shower/day Teeth cleaning 2/day	Low flow shower heads Low flow taps Change attitudes to personal bathing Digital / smart showers Teeth cleaning without water	Recycling showers Waterless showers Creating spaces to relax without water
Clothes washing	Hand clothes washing Weekly washday	Twin tub washing machines Emergence of front loader washing machines Washing on demand	Water & energy efficient washing machines Wear clean clothes every day	More efficient washing machines	Self cleaning clothes Waterless washing machines
Dish washing	Hand dish washing Daily dish washing	Emergence of dish washing machines Daily dish washing	Increased uptake of water & energy efficient dishwashers	More efficient dishwashers	Self cleaning dishes and utensils Waterless dishwashers
Cleaning Cooking Drinking	Water based cleaning More tap water drunk More washing of garden produce Fewer pets		More use of cleaning products More bottled water & drinks More ready meals More pets	Smart lower flow taps Change attitudes to water wastage – not leaving taps running Potentially more tap water used for drinking (moving away from bottles)	Waterless chemical free cleaning - Nanotechnology Increase in point of use treatment/conditioning of tap water
Plumbing losses	Plumbing losses largely due to cistern inlet valves, taps and joints Syphon flush systems – no leaks	Growth in the number of appliances attached to the plumbing system	Increased numbers of leaking WCs from drop valves	Leak free WC flush designs Change attitudes to water wastage - leaks	Non drip tap designs Leak free plumbing IoT growth in home leak detection and warning systems
Water use outside the home					
Garden/lawn watering	More garden grown produce Use of RWH for garden use	Smaller gardens, less garden produce more lawns & patios Green lawns – more watering		Smarter RWH and GWR systems for gardens Smart irrigation systems	Drought resistant plants/lawns Design of new homes have RWH or GWR included for garden use
Car washing	Fewer cars Use of buckets for washing Sunday car washing routine	More cars	More use of 'pop up' car cleaning facilities Cars cleaned away from the home	Waterless car washing products	Stay clean technology for car paints/coatings
Hard surface washing	Use of buckets (recycled water and brushing for washing	Pressure washers for patio and decking washing		Use recycled water for cleaning	
Customer supply pipes	Largely unaware of CSP leaks	Increased metering leads to greater awareness Different policies for repair/replace in different companies		Potential issues with domestic fire sprinklers Greater support/help for repair/replace	Smart meter detection and alarm Smart Apps for customers

5. Scenarios: 5.4. Methodology for modelling household consumption

To model the long-term potential for demand reduction in households in England and Wales, a stochastic micro-component modelling approach has been used. The model possesses inherent randomness, which will lead to an array of results from which uncertainties can be derived.

The starting point, is to calculate current and future PCC using a micro-component model. Household consumption is broken down into micro-components (WC flushing, showering, clothes washing, tap use, etc.). Each micro-component is calculated using values for ownership, volume per use and frequency of use (O, V, F). This allows us to make assumptions about how scenarios impact each element of water use in the home. The model inputs also allow us to vary factors such as occupancy and meter penetration (this is used to explore the impact of each scenario in the four geographic regions in England and Wales).

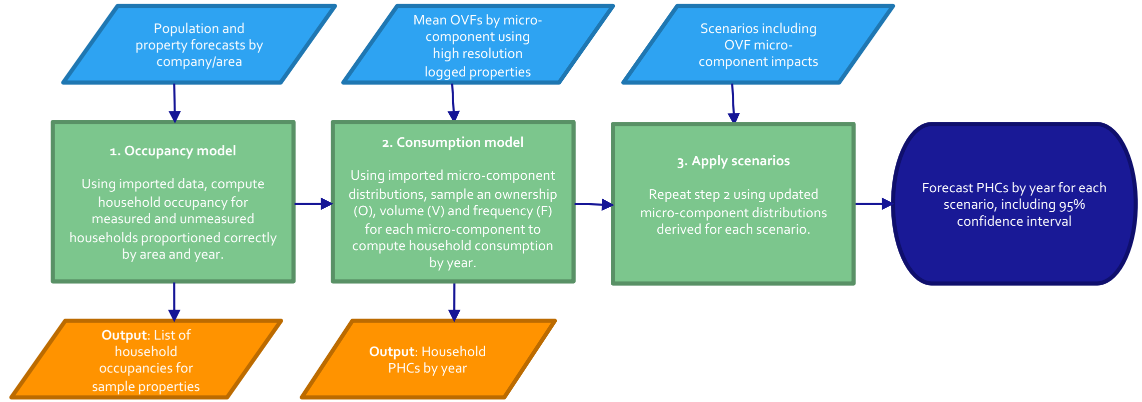
The assumptions in the model are described in Table 6, and the modelling process is described in Figure 17. The model was calibrated by scaling the base year micro-components to reported household consumption. A more detailed description of the modelling process and the assumptions used in modelling each scenario are presented in Annex D.

The next few pages present the outputs of the modelling, and illustrate what water use in homes could look like under each scenario in 50 years time.

Table 6: Assumptions used in the stochastic micro-component model

Assumption	Impact
Micro-components can be well described as well-known distributions	With the exception of losses and external use, the micro-components are assumed to be well described by probability distributions. This allows the mean and standard deviations to be altered in the scenarios, but may not fully show the randomness of some micro-components.
Frequency of use only depends on occupancy	Mean frequency of use has been determined per micro-component.
Volume per use varies per household, and is not fixed per micro-component	A single household may have differing toilet flush volumes, however this means that multiple appliances can be modelled, and reduces the probability of over-sampling from the extremes of the distribution
The OVF distributions do not change in the scenarios, the mean and standard deviations do.	The micro-components are assumed to behave in the same way probabilistically, when considering scenarios, however they may have altered means and different variance.
All measured properties can be treated as one group	The model currently only considers measured and unmeasured populations due to the high resolution data available. However, optants and compulsorily metered properties may behave differently, which are not modelled here.
Losses are assumed to be independent of occupancy	This is largely true, however larger occupancy households are likely to be larger homes with more appliances. Having more appliances may mean a higher probability of an internal leak, which is not currently modelled.
External use is assumed to be independent of occupancy	Within the data set analysed to derive the OVFs, this seems to be the case. However, if external use is related to occupancy, then this is not currently modelled.

Figure 17: Overview of modelling process



5. Scenarios: 5.5. Scenario modelling outputs – trends

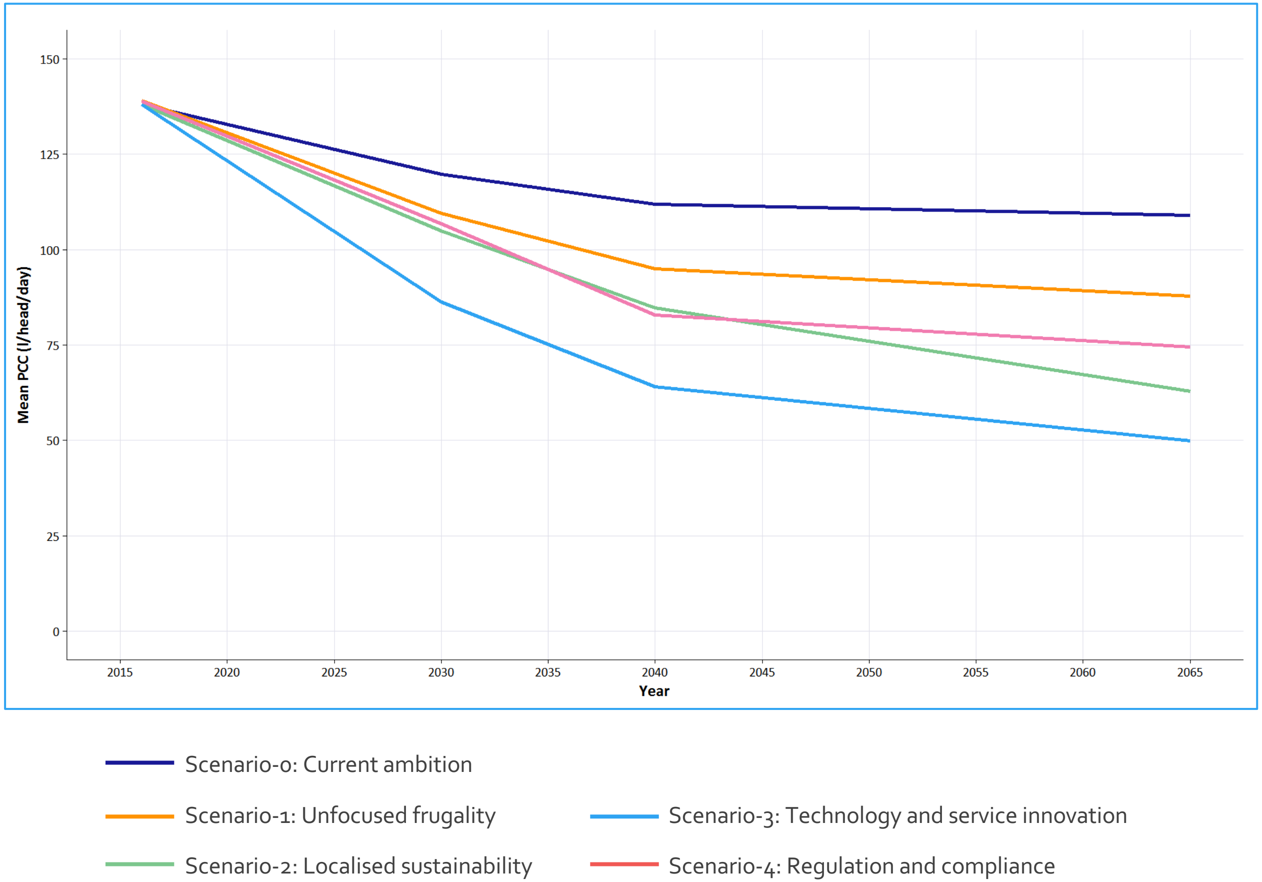
Figure 18 shows the trends for normal year household PCC (excluding supply pipe losses) from the model for each scenario for England and Wales. The current ambition scenario reaches a PCC value of 105 l/head/day in 2065. The deepest reduction is seen in Scenario-3 Technology and service innovation. This scenario reaches a PCC value of 49 l/head/day, which by today's terms may seem excessive but this is a view 50 years into the future. On the next page we explore exactly what this means for each micro-component of water use in the home.

The 50 year PCC values under each scenario for each region are presented in Table 5.

Table 5: PCC results (l/head/day) for each scenario and each area

Scenario:	0	1	2	3	4
England & Wales	105	86	62	49	73
South East	110	91	65	51	76
South West	100	80	58	46	69
Central	108	87	62	49	74
North	92	76	55	44	64

Figure 18: Modelled PCC trend results for England and Wales for each of the five scenarios



5. Scenarios: 5.5. Scenario modelling outputs – micro-components

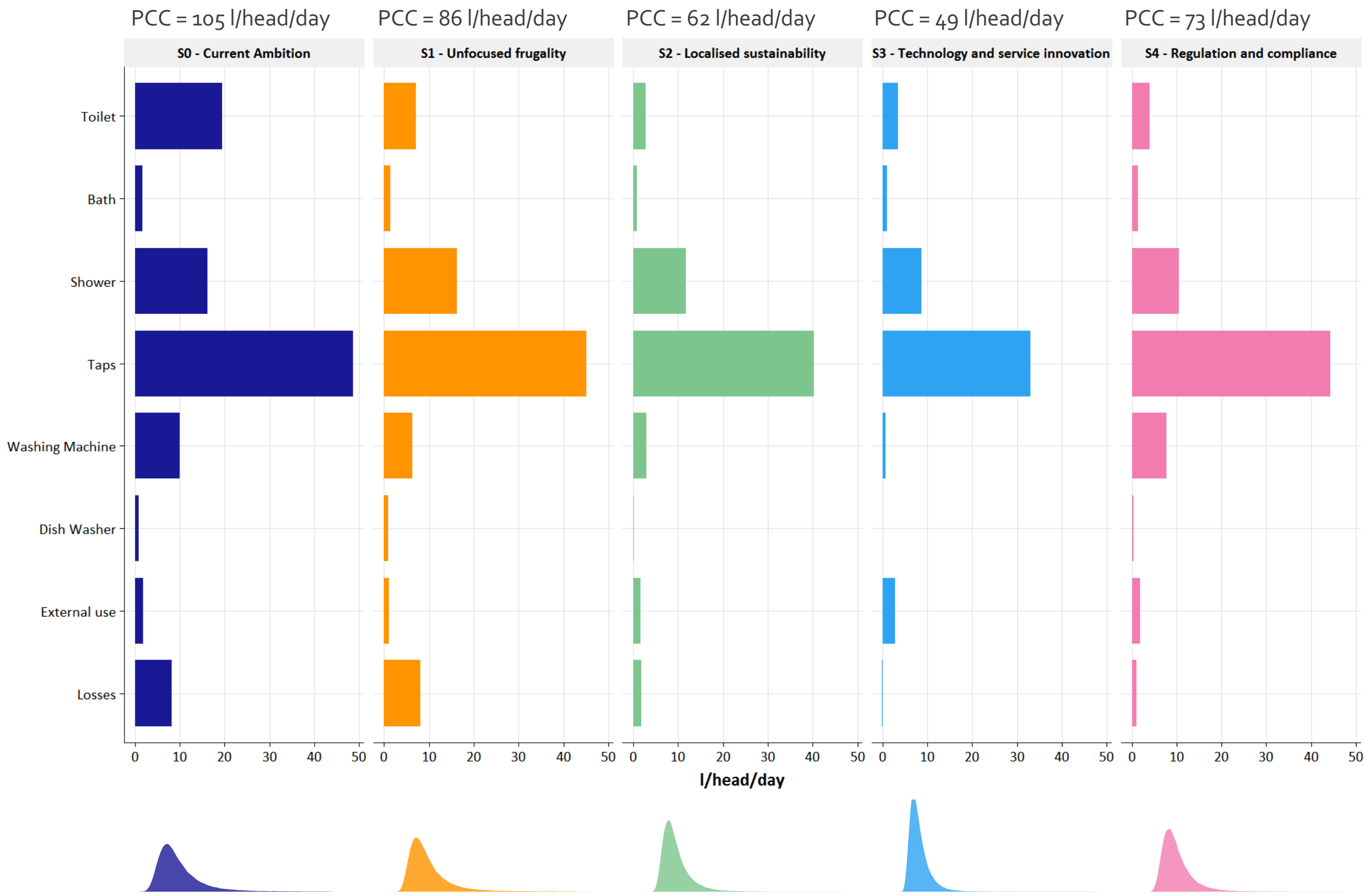


Figure 19: Modelled micro-components of household water consumption for England and Wales in 50 years for each of the five scenarios

Figure 19 shows how the micro-components of water consumption in the home (excluding supply pipe losses) vary across the scenarios in 50 years time.

This starts to indicate what has to be achieved if the PCC ambitions under each scenario are to be realised in 50 years.

Table 6 on the next page explains how each of the micro-component values are achieved.

The distribution plots at the bottom of Figure 18 show the spread of PCC values for each scenario. The 'Current ambition' has the widest distribution, and the 'Technology and service innovation' scenario has the tightest spread of results because it is relying less on personal behaviour to achieve the savings. The distributions also give an indication of the uncertainty.

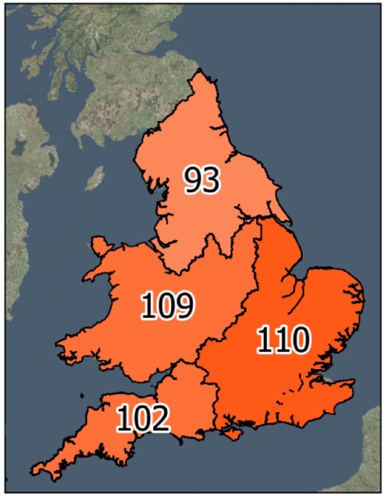
5. Scenarios: 5.5. Scenario outputs – explanation of micro-component values

Micro-component	S0: Current ambition (PCC = 105 l/head/day)	S1:unfocused frugality (PCC = 86 l/head/day)	S2: Localised sustainability (PCC = 62 l/head/day)	S3: Technology and innovation (PCC = 49 l/head/day)	S4: Regulation and compliance (PCC = 73 l/head/day)
Toilet	Replacement of older larger cisterns continues and future regulations limit new installations.	Current market transformation to continue reduction in toilet flush volumes. Increased frugality – "if it's yellow let it mellow". Some flushing with bath/shower water.	There is an existing toilet at 1.5 litres (Propelair). If 50% toilets use non-potable water used (e.g. rainwater or greywater) and 50% @1.5 litres, then this is achievable.	There is an existing toilet at 1.5 litre (Propelair). If 50% @1.5 litres, and waterless toilets are developed for the other 50%, then this is achievable.	Regulation to push much lower flush volumes into the retrofit market. Limited use of non potable water for toilet flushing. Existing home retrofits via water neutrality regulation.
Bath	Bath use declines slowly without any specific interventions.	Assumption that baths become less frequent. Bathing limited to pets and children. Bathing reduces through frugality in this scenario.	Assumption that baths become less frequent. Bathing limited to pets and children. Bathing reduces through behaviour change in this scenario.	Assumption that baths become less frequent. Bathing limited to children. Bathing reduces through technology (smaller baths) in this scenario.	Assumption that baths become less frequent. Bathing limited to pets and children. Bathing reduces through behaviour change in this scenario.
Shower	Water companies focus their efforts on reducing shower consumption via "four minute shower" messages, timers, apps etc. Smart shower take up increases, some recycling showers emerge towards the end of time-line.	Shorter showers, flow controls and reduced frequency of use.	Some smarter digital showers and recycling showers to reduce volumes. Otherwise relies on shorter, less frequent and lower flow showers (just that people do this voluntarily in this scenario!).	Would be delivered through recycling showers – currently available (£3k) but deliver 90% saving. Prices fall as demand increases. Also digital showers for programming soaping/rinsing.	Regulation and water labelling delivers market transformation towards widespread take up of recycling and digital showers.
Taps	Water companies continue to focus on behaviour change messaging, targeting metered customers with highest consumption.	Following current guidance on not washing under running tap, turning off for teeth, shaving etc.	Non-potable water provision for laundry (hand washing), cleaning, etc.	Smart taps – no waste. Boiling water / chilled water taps – no running to waste. Technology for clothes and crockery/pans etc. to reduce the need for cleaning. Non-water based cleaning technologies.	Normal market transformation plus behaviour change. New developments are water neutral.
Washing machine	No specific interventions but planning controls mean more new properties have non-potable feeds for laundry.	More efficient washing – full loads, use of eco-cycles on products.	Extensive use of non-potable water for washing machines in new developments and retrofits.	Combination of waterless washing machines and non-potable water use.	Water labelling delivers more efficient products.
Dishwasher	No specific interventions.	More efficient washing – full loads, use of eco-cycles on products.	Extensive use of non-potable water for dishwashers in new developments and retrofits.	Combination of waterless machines and non-potable water use (e.g. with point of use disinfection).	Water labelling delivers more efficient products.
External use	Increased public awareness of water scarcity delivers some reductions and more new properties have non-potable feed for external use.	Less external use generally – more use of water butts.	Widespread use of rainwater/non-potable water.	Small reduction with smart irrigation.	Regulation drives water butts and xeriscaping.
Plumbing losses	Leaky loos recognised as an issue. Water companies offer free fixes and discounted replacements.	Frugality drives greater focus on losses especially in the home.	Services for loss detection and repair delivered as part of widespread markets.	Losses reduced to zero through smart meters, smart households, and leak free toilets.	Regulation drives down losses through products, labelling and behaviour change.

5. Scenarios: 5.5. Scenario outputs – summary by region 2065

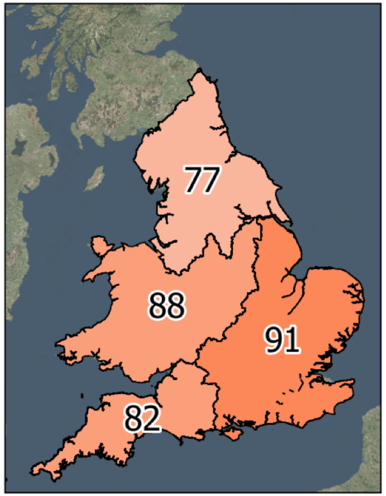
Figure 20: Scenario outputs for each of the geographic areas by 2065

Current ambition



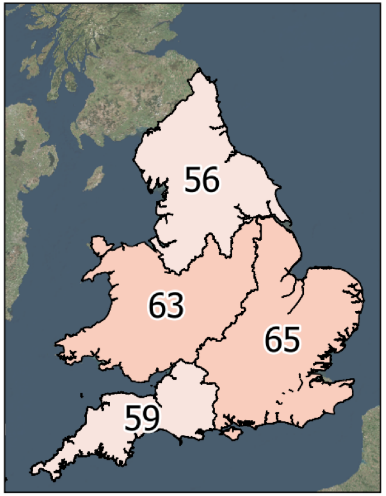
This scenario illustrates how household consumption (expressed as per capita consumption in litres/head/day) will continue to reduce, broadly at the rate seen in recent years. The key question for this scenario is whether this gradual reduction in use is enough.

Unfocused frugality



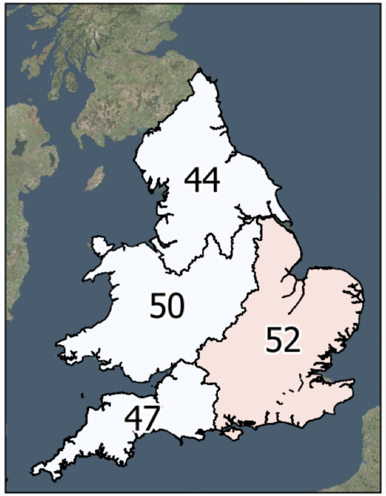
This scenario illustrates the consequences of a relatively disorganised and directionless effort to reduce consumption beyond current ambition. The impacts of this are largely negative in terms of resilience, customer service and other variables and outcomes are relatively uncertain.

Localised sustainability



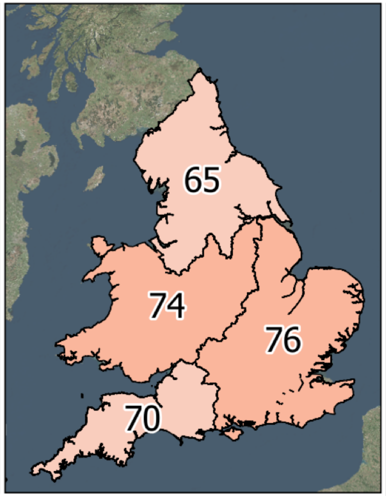
This scenario is achieved via a vibrant and varied market for local water services which is well integrated with other aspects of the urban and natural water cycle. This requires new institutional and funding arrangements, bringing some risk, but overall this is an innovative, affordable and resilient scenario. Outcomes are somewhat uncertain.

Technology and service innovation



In this scenario demand reductions are delivered via much more efficient products, smart devices and competition for water services. Whilst this scenario is highly innovative, there is a risk of consumer inequities due to affordability and levels of service may also be inconsistent. Uncertainty of outcomes are low in this scenario.

Regulation and compliance



In this scenario demand reductions are achieved through and combination of regulation of products and the sector as a whole, including tariffs to deliver behaviour change. These may result in winners and losers, and potential challenges with regards to fairness. Innovation is limited and controls on water availability may constrain levels of service.

6.1. Discussion of findings

The study considers the potential for making deep reductions in household water consumption and water lost from customer supply pipe leaks, up to 2065.

Pressures from increased demand, driven largely by population growth, and the effects of climate change on resource availability will have long term impacts on the water sector's ability to deliver services that are resilient and affordable.

The population of England and Wales is expected to grow by 18% by 2065 (ONS, 2017). By 2050, climate change is expected to lead to a reduction of around 6-11% in the amount of water available for public supply, whilst total UK demand is projected to increase by between 2-9% over the same period (and by 4-18% by the 2080s) (HR Wallingford, 2015). The industry is acting in a number of ways at present to mitigate these pressures, but more will need to be done to meet or improve on current levels of customer service.

We have used data analysis, literature reviews, stakeholder consultation (including government, regulators, water companies, NGOs, trade bodies and academia) and modelling to identify a wide range of potential response measures that could be implemented to help address these challenges. This identified many disparate views on how to deliver resilient affordable water services in the face of increasing population growth and climate change.

Three specific proposals came through strongly in stakeholder feedback: mandatory labelling for water using products, tackling the growing problem of leaky loos and increasing the current proportion of metered households.

Mandatory labelling has proven to be very effective in reducing consumption in Australia by about 30 to 40 litres/household/day (Fyfe et al 2015), and there is widespread support for this amongst stakeholders.

Research presented in section 2.2 of this report indicates that leaking toilets are a significant barrier to reducing household consumption, along with other internal plumbing losses.

Section 2.4 of this report illustrates that increasing the proportion of households on a meter could reduce mean consumption by 16%. Based on this, we have included these three measures as potential first steps to delivering long term reductions in household water consumption.

Customer supply pipe leakage currently accounts for 8% of total household water demand. There are about 225,000 km of customer supply pipe assets in England and Wales, with no strategic asset management plan. Companies face complex issues when trying to reduce water losses in this area; most notably customer understanding, identification of losses and the cost of reinstatement. There are large reductions to be made, and some companies will begin to deliver these in the next 10 to 15 years. But there are significant challenges to the delivery of these savings.

We identified approximately 80 different measures which could deliver deep reductions in household consumption.

Short-term, no-regret options include the scaling-up of activities that the sector is currently delivering, such as smart home retrofit visits, community scale rainwater harvesting and water reuse schemes. Such measures could be implemented more widely in the near future without significant innovation.

We have also identified market-ready technologies that could be adopted more widely in the short to medium-term such as recycling showers, smart white goods and ultra-low flush toilets. These could followed by technology innovation on even more efficient products such as waterless toilets. Additional measures were identified that affect the governance, funding or regulation of water service providers including natural capital accounting, utility bundling and water neutrality for new developments.

We found that there is a general appetite for deeper demand reductions over the long term - most respondents (who provided a figure) thought that consumption rates between 75 and 100 l/head/d could be achieved by 2065. Achieving this will require change in the way the water sector operates.

6.1. Discussion of findings (continued)

To explore this, we developed five scenarios to illustrate what future water use might look like in 50 years' time, with different drivers, pressures, responses and impacts.

The scenarios provide useful insights into what the future for water services and demand might look like. Reality will of course be different, and will depend on action we take in the next few years. Fundamentally, more action is needed to ensure water services are sustainable, resilient and affordable well into the future.

We modelled future demand by breaking household consumption down into its components of water use, and describing how each of these components is likely to change from different demand measures under each of the scenarios. In exploring these deep reductions in demand we sought to maintain a good level of utility and quality of water use.

Two of these scenarios present the most positive outcomes for customers and the environment. Under 'Localised Sustainability' (PCC = 62 l/head/day), water scarcity is recognised as an issue, and there is widespread, local competition for water services, resulting in a positive effect on consumer behaviour.

In contrast, under, 'Technology and Service Innovation' (49 l/head/day) the water scarcity challenge will be tackled through extensive use of water efficient technology, home automation as well as service innovation (e.g. utility bundling, and maintaining water using products). Innovation will need to be encouraged and incentivised, through leadership, competition, provision of open data and engagement with academia.

Any deep reduction in water use will also require a much greater awareness of water scarcity issues in the UK, and this should be combined with strong leadership in co-ordinated and concerted actions to deliver long term reductions in household demand.

Both these scenarios will require much greater levels of competition and innovation than currently present in the water sector.

Government and regulators can put incentives in place to promote greater competition. Innovation can be encouraged through greater collaboration and the provision of open data on water use. Behaviour change will require us to better understand water use in homes and communities, and how to influence it.

The infographic in Figure 21 on the next page shows the impact under different scenarios on the total amount of water demanded by households from the distribution system (that is household consumption and customer side supply pipe losses).

The scenario results for 2065 indicate that PCCs between 105 and 50 l/head/day) are possible. It is worth noting that approximately 22% (just over one fifth) of the measured population in 2016 already have a PCC of 75 l/head/day or below.

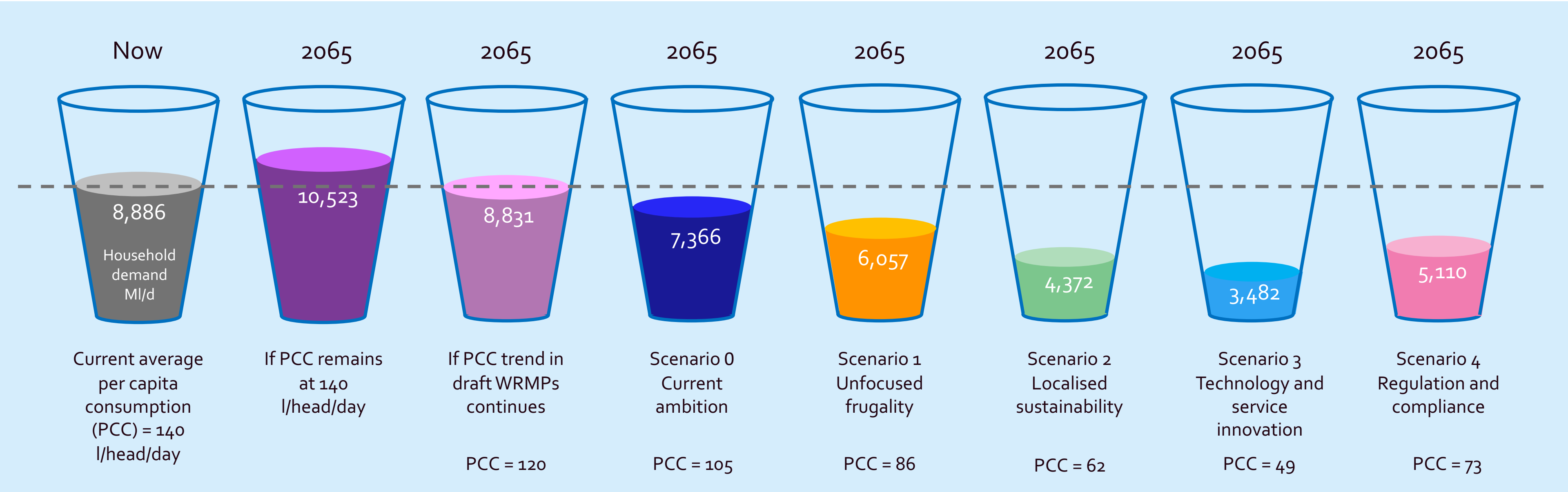
Potential costs and other implications such as the impact on the wastewater network or stranded assets are outside the scope of this project, and should be addressed in future studies.

This project has focused on the potential for deep reductions in household demand, through behaviour change, services and technologies, and illustrated how this could be achieved.

To move beyond 'business as usual' and start to deliver the kind of reductions in household water demand that will be required under any of the scenarios, a number of actions are needed. These are presented in Section 7 as the first steps to delivering these deep reductions, and will allow a broad range of stakeholders to contribute towards this ambition.

6.2. Summary of impacts

Figure 21: The volume of household water demand (in Ml/d) now, and in 2065 under a range of different scenarios



The volumes quoted are Ml/d, and assume current ONS population growth for England and Wales to 2065. The dotted line represents the volume used now for household demand. This illustrates how demand measures could reduce the amount of water needed for household demand, offsetting some of the pressures on long term resilience.

7. First steps to delivering deep reductions in household demand

1 **Leadership for concerted action.**

Strong leadership to ensure that water companies, government, regulators, the supply chain, academia, innovators and others work in a concerted and coordinated way.

2 **Monitor and support.**

Monitor progress towards deep reductions in household water demand, and provide support for the ongoing business cases for water efficiency.

3 **Metering and tariffs.**

Meter all domestic properties to facilitate future savings through customer behaviour, utility services, water saving technologies and further research on tariffs.

4 **Water labelling.**

Mandate water labelling for water-consuming products to help consumers select suitably water efficient products.

5 **Leaky loos.**

Tackle losses from leaky loos through product standards for new toilets, along with monitoring and fixing of plumbing losses.

6 **Customer supply pipes.**

Develop a strategy to reduce customer supply pipe losses and maintain these assets in the future.

7 **Behaviour change.**

Prioritise research into behaviour change for influencing consumer choice of products and changing water use practices.

8 **New development and growth.**

Update planning rules to require new developments to be water efficient, e.g. through community rainwater harvesting and water reuse.

9 **Open data.**

Make performance data openly available to encourage and facilitate innovation in services and technologies.

References

Artesia (2012): Report on leaky toilets project. Ref: AR1053. Artesia Consulting 2012.

Artesia (2017): Planning for the future: a review of our understanding of household consumption. Ref: AR1170, Artesia Consulting 2017.

Browne et al (2013): Patterns of Water: The water related practices of households in southern England, and their influence on water consumption and demand management, Browne, A. L., Pullinger, M., Anderson, B. & Medd, W. Lancaster University, 2013.

Defra (2018), A Green Future: Our 25 Year Plan to Improve the Environment, Defra, 2018.

Clayton (nee Gardner), K. (2010): Residential water demand modelling and behavioural economics, University of East Anglia, previously published as Gardner, K. (2008), Advice on Residential Price Elasticity Estimates for Water Demand in the United Kingdom, advice provided to ICS Consulting.

Fyfe, J., McKibbin, J., Mohr, S., Madden, B., Turner, A., Ege, C., (2015), Evaluation of the Environmental Effects of the WELS Scheme, report prepared for the Australian Commonwealth Government Department of the Environment by the Institute for Sustainable Futures, University of Technology, Sydney.

Hassell (2016): Adolescents and showering – in their own words. Hassell, C., ech$_2$o report, August 2016.

Herrington (1996): Climate change and the demand for water, Herrington, P., 1996.

HR Wallingford (2015): CCRA2: Updated projections for water availability for the UK Final Report.

Komives, K., Foster, V., Halpern, J., Wodon, Q., 2005: Water, Electricity and the Poor: Who Benefits from Utility Subsidies? Directions in Development. The World Bank, Washington, DC.

Ofwat (1999): Patterns of demand for water in England and Wales: Ofwat , 1989-1999.

ONS (2017): National Population Projections. Office for National Statistics

Ornaghi and Tonin (2017): The effect of metering on water consumption – policy note. Ornaghi, C. (University of Southampton), and Tonin, M. (Free University of Bozen-Bolzano), May 2017.

Ricardo (2015): Leaky Loos Phase II. Water Industry Collaborative Fund Project. Ricardo, 2015.

Shikun Sun, et al (2016): Shikun Sun,Yubao Wang,Jing Liu,Huanjie Cai,Pute Wu,Qingling Geng,Lijun Xu (2016) Sustainability assessment of regional water resources under the DPSIR framework. Journal of Hydrology Volume 532, January 2016, Pages 140-148.

UKWIR (2009): Issues regarding the potential adoption of supply pipes: costs, customer service and regulatory impacts. Report ref. 09/CU/01/4. 2009.

UKWIR (2013): Valuing Water, Phase 1, Report ref: 13/RG/07/27.

UKWIR (2014): Supply Pipe Ownership - The Customer View. Report ref: 14/CU/01/8.

UKWIR (2015): The economics of supply pipe leakage. Report ref: 15/WM/08/56.

UKWIR (2016): Integration of behavioural change into demand forecasting and water efficiency practices. Report ref. WR01A214, 2016.

Water UK (2016): Water Resources Long Term Planning Framework. (2015-2065). Technical Report Final 20 July 2016.

Waterwise (2017): Water Efficiency Strategy for the UK, Waterwise June 2017.

WRAS 2005: Information and guidance note, No. 9-02-03 issue 2, Conservation of Water, 2005.

WRc (2005): Increasing the Value of Domestic Water use Data for Demand Management (CP187), WRc, 2005.

This report has been produced by Artesia Consulting for Ofwat to examine the long term potential for making deep reductions in household water demand.

Any enquiries about this report should be directed to:

Rob Lawson at Artesia Consulting at the following email: rob@artesia-consulting.co.uk

Artesia Consulting provides technical services in water resources planning, leakage management, demand forecasting, water conservation, metering, smart metering, data analysis, mathematic modelling and statistics.

For more information about Artesia please visit: www.artesia-consulting.co.uk

Artesia
Consulting