Title:	**Report AR1206 Annex B** **Water demand reduction measures**		
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This document is one of five technical annexes that accompany the main report "The long term potential for deep reductions in household water demand" produced for Ofwat by Artesia Consulting.

This technical annex provides details of the consultations, reference work and identified water saving product research on measures that are could be used to make reductions in water demand in England and Wales over the next fifty years.

1. Introduction

The primary objective of this project was to understand the long-term potential for demand management in domestic properties in England and Wales. A crucial part of this project was therefore to analyse and present the options available for making deep reductions to per-capita consumption over a minimum fifty-year period (looking ahead at least to 2065).

Options for reducing water demand have been identified from a range of sources including:

- A review of current water company draft Water Resources Management Plans;
- A literature review of academic papers via Google Scholar;
- A consideration of relevant behavioural economics approaches;
- Engagement via emailed questions and responses to around key 40 stakeholders, followed by more in-depth discussions with a smaller selection of representative stakeholders;
- On-line searches for new technologies, approaches and systems;
- Patent search; and
- A review of approaches to efficiency in other sectors, particularly energy.

The results of these searches are summarised in section 2. The list of measures considered for analysis in this project is presented in section 3, along with an analysis of their potential to reduce consumption and over what time period.

2. Research results

2.1. Online research and review of draft water company plans

A representative selection of the water company draft Water Resources Management Plans (WRMPs) were reviewed to identify what water efficiency measures water companies are currently planning to deliver over the next 25 to 50 years.

This identifies a range of common measures including:

- Delivering household retrofits of water using devices in a range of ways, including targeting specific types of households.
- Increased rates of household metering – based on different metering strategies from encouraging more people to opt for a meter, metering on change of occupier to compulsory metering.
- Exploration of measures such as rainwater harvesting and grey water recycling.

Evidence from these plans, combined with feedback from some water companies, and informal online research revealed a number of measures for reducing household water use which are either in progress at the moment, or could be rolled out more widely in England and Wales in the next few years. These are presented in Table 1.

Table 1 Summary of 'near present' measures for reducing household water consumption

Name of measure	Description	More information
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.	http://www.propelair.com/homepage/
Albion Water – Rissington development	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.	https://www.albionwater.co.uk/developers/our-projects/upper-rissington-gloucestershire
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.	https://www.thameswater.co.uk/Be-water-smart/Were-water-smart
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.	http://www.nwcambridge.co.uk/vision/sustainability/water-recycling
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).	https://www.bundles.nl/en/product/miele-washing-machine-wkg-120-wcs/
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.	https://www.energiesprong.uk/
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.	https://www.aqualisa.co.uk/showers/smart?Sort=Name-ASC

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.	http://www.waterrating.gov.au/choose/water-rating-label
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.	https://www.greenredeem.co.uk/thameswater
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.	https://beta.southernwater.co.uk/the-news-room/the-media-centre/2018/march/the-next-stage-in-our-water-saving-journey
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.	http://thirsty.watersmart.com/blog/thinking-outside-the-bill
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.	http://www.smarterdrop.com/
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.	https://orbital-systems.com/
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.	https://www.cranfield.ac.uk/case-studies/research-case-studies/nano-membrane-toilet

2.2. Literature review

The UKWIR report "Integration of behavioural change into demand forecasting and water efficiency practices" included an extensive literature search of academic papers on household water use and its drivers[1]. The results of the UKWIR research have been incorporated into this project. The literature review in this project was therefore undertaken to ensure any recent relevant academic research on household demand management was considered in this study. The review was carried out using Google Scholar and using the following search terms:

"residential water efficiency", "water conservation strategy" (or "strategies"), "residential water behaviour". Replace "residential" with "household", include "patterns", "analysis".

This resulted in the following papers being identified.

Matthew D. Bartos and Mikhail V. Chester (2014) "The Conservation Nexus: Valuing Interdependent Water and Energy Savings in Arizona" Available at: https://pubs.acs.org/doi/abs/10.1021/es4033343
Yiwen Bian a, Shuai Yan a, Hao Xu (2014) "Efficiency evaluation for regional urban water use and wastewater decontamination systems in China: A DEA approach" Available at: https://www.sciencedirect.com/science/article/pii/S0921344913002553
Bruk M. Berhanu, Michael Blackhurst, Mary Jo Kirisits, Paulina Jamarillo, Derrick Carlson (2016) "Feasibility of Water Efficiency and Reuse Technologies as Demand-Side Strategies for Urban Water Management" Available at: http://onlinelibrary.wiley.com/doi/10.1111/jiec.12430/full
Marie-Estelle Binet, Fabrizio Carlevaro, Michel Paul (2014) "Estimation of Residential Water Demand with Imperfect Price Perception" Available at: https://link.springer.com/article/10.1007/s10640-013-9750-z
A.Cominola, M.Giuliani, D.Piga, A.Castelletti, A.E.Rizzoli (2015) "Benefits and challenges of using smart meters for advancing residential water demand modeling and management: A review" Available at: https://www.sciencedirect.com/science/article/pii/S1364815215300177
Alison Browne, Will Medd, Martin Pullinger and Ben Anderson (2014) "Distributed Demand and the sociology of water efficiency" Available at: https://www.research.ed.ac.uk/portal/files/24323955/Browne_et_al_2014_Distributed_Demand_and_the_sociology_of_water_efficiency_1.pdf
A. M. Fidar, F. A. Memon & D. Butler (2015) "Economic implications of water efficiency measures I: assessment methodology and cost-effectiveness of micro-components" Available at: https://www.tandfonline.com/doi/abs/10.1080/1573062X.2016.1223859
Thulo Ram Gurung, Rodney A. Stewart, Cara D. Beal, Ashok K. Sharma (2014) "Smart meter enabled water end-use demand data: platform for the enhanced infrastructure planning of contemporary urban water supply networks" Available at: https://www.sciencedirect.com/science/article/pii/S0959652614009846
J.J. Harou, P. Garrone, A.E. Rizzoli, A. Maziotis, A. Castelletti, P. Fraternali, J. Novak, R. Wissmann-Alves, P.A. Ceschi (2014) "Smart Metering, Water Pricing and Social Media to Stimulate Residential Water Efficiency: Opportunities for the SmartH2O Project" Available at: https://www.sciencedirect.com/science/article/pii/S1877705814023376
Ariane Liu, Damien Giurco, Pierre Mukheibir (2015) "Urban water conservation through customised water and

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

end-use information" Available at: https://www.sciencedirect.com/science/article/pii/S095965261501383 9
Elena Maggioni (2015) "Water demand management in times of drought: What matters for water conservation" Available at: http://onlinelibrary.wiley.com/doi/10.1002/2014WR016301/full
D. Manouseli, S. M. Kayaga, R. Kalawsky (2017) "Evaluation of water efficiency programs in single-family households in the UK: a case study" Available at: http://ws.iwaponline.com/content/17/6/1785
C. Mini, T. S. Hogue, S. Pincetl (2014) "Patterns and controlling factors of residential water use in Los Angeles, California" Available at: http://wp.iwaponline.com/content/16/6/1054
C. Mini, T.S. Hogue, S. Pincetl (2015) "The effectiveness of water conservation measures on summer residential water use in Los Angeles, California" Available at: https://www.sciencedirect.com/science/article/pii/S0921344914002237
James I. Price a, Janie M. Chermak, Jeff Felardo (2014) "Low-flow appliances and household water demand: An evaluation of demand-side management policy in Albuquerque, New Mexico" Available at: https://www.sciencedirect.com/science/article/pii/S0301479713007184
K. Rathnayaka, S. Maheepala, B. Nawarathna, B. George, H. Malano, M. Arora, P. Roberts (2014) "Factors affecting the variability of household water use in Melbourne, Australia" Available at: https://www.sciencedirect.com/science/article/pii/S0921344914001815
K. Rathnayaka, H. Malano, M. Arora, B. George, S. Maheepala, B. Nawarathna (2017) "Prediction of urban residential end-use water demands by integrating known and unknown water demand drivers at multiple scales II: Model application and validation" Available at: https://www.sciencedirect.com/science/article/pii/S0921344916303317
A.E. Rizzoli, A. Castellettib, A. Cominolab, P. Fraternalib, A. Diniz dos Santos, B Storni, R. Wissmann-Alvese, M. Bertocchi, J.Novak, I. Micheelg (2014) "The SmartH2O project and the role of social computing in promoting efficient residential water use: a first analysis" Available at: http://porto.polito.it/2671485/1/iemss2014_submission_294.pdf
Giulia Romano, Nicola Salvati and Andrea Guerrini (2014) "Estimating the Determinants of Residential Water Demand in Italy"Available at: http://www.mdpi.com/2073-4441/6/10/2929/html
Yixing Shan, Lili Yang, Kim Perren, Yanmin Zhang (2015) "Household Water Consumption: Insight from a Survey in Greece and Poland" Available at: https://www.sciencedirect.com/science/article/pii/S1877705815026715
P. Wesley Schultz, Alyssa Messina, Giuseppe Tronu (2014) "Personalized Normative Feedback and the Moderating Role of Personal Norms. A Field Experiment to Reduce Residential Water Consumption" Available at: http://journals.sagepub.com/doi/abs/10.1177/0013916514553835

2.3. Behavioural economics

Behavioural economics is regarded as having a role to play in affecting consumer behaviour generally, and in water efficiency specifically. The measures presented in Table 2 have been identified as potential behaviour-based measures.

Table 2 Potential behaviour-based measures

Option name	Description
Price-based	
Metering	Compulsory, change of occupancy or request metering, with flat rate tariff
Increasing block tariff	Rate per unit of water is low for the initial (lower) block of consumption and increases as the volume of consumption increases. Impact depends on elasticity of demand[2] and may require smart metering to provide timely customer feedback and be most effective.
Decreasing block tariff	Rate per unit of water is high for the initial (lower) block of consumption and decreases as the volume of consumption increases. Suitable for consumers with high consumption levels (generally industry and commercial). Penalises consumers with low level of consumption and provide a disincentive for water efficiency.
Variable tariffs	Rate per unit is varied by time of day. Impact depends on elasticity of demand and may require smart metering to provide timely customer feedback and be most effective.
Seasonal tariffs	Rate per unit is varied by time of year (e.g. to mitigate outdoor water demand increases in summer months). Impact depends on elasticity of demand and may require smart metering to provide timely customer feedback and be most effective.
Behaviour-based	
Information provision	Reference points and other people's behaviour matters, and social comparison is a key driver of behaviour, which is dependent on availability of information, advice and feedback. Option could involve provision of comparative (e.g. close neighbours) average consumption information on 'smart bills', and on what 'the majority of customers' do to save water. Likely to be most effective amongst high water users.
Automatic enrolment	Habitats are ingrained and hard to change. Rather than asking people to volunteer to be involved in a water efficiency programme, this option would tell them they will automatically be included (and the reasons why) unless they specifically elect to opt-out.
Eco-branding	People are motivated to 'do the right thing' and generally care about societal and environmental goals. Option could include provision of free or subsidised water efficiency devices, which is eco-branded rather than using language which may be perceived as having a negative impact in utility (e.g. low flow). Could be accompanied by information on contribution of water efficiency to local environmental (e.g. river flow) and social (e.g. affordability) goals. Likely to appeal to subset of customers only.
Home water reports	Just giving people the incentives and information is not necessarily enough, they need to feel they are making a difference. Option could include provision of personalised tips for saving water, and how the customer is contributing to wider context.
Interest-free loans	Loans to install devices, e.g. ultra-low-flow toilets and showerheads, which are paid off as part of the water bill. Assuming water is metered, the water saving will offset the cost of the repayments making the equipment appear effectively free (and water bills would be cheaper in the future). Thus, immediate financial losses are avoided.
Penalty charge	Driven by loss aversion (observation that consumers value losses more highly than gains).

[2] Estimates of elasticity for domestic demand are generally in the range -0.1 to -0.5 (i.e. for every 1% increase in the tariff level, demand falls by 0.1-0.5%). However, there is important variability in this, with elasticity significantly higher when water is potentially more scarce (e.g. in summer) and for higher income groups. See UKWIR (2014) Valuing Water and Komives et al. (2005) Water, Electricity and the Poor: Who Benefits from Utility Subsidies? Directions in Development. The World Bank, Washington, DC.

	Customers are provided with a fixed (e.g. daily) water allowance. Every time (e.g. day) this is exceeded, they incur a penalty charge.
Water lottery	Customers are provided with a fixed (e.g. daily) water allowance. If they stay within this allowance for a fixed period (e.g. month) they are entered into a lottery to win a cash or other prize.
Value of water	Customers' water usage is translated into monetary values, so they can see the benefit of savings. May be most effective with lower income customers.
Setting a goal/making a pledge	Customers are provided with information on where and how they can make water savings. They have a fixed (e.g. daily) allowance (lower than their existing use), and could be rewarded/punished if they meet/fail to meet this.
Community competition	A competition between communities (e.g. towns or villages) to save the most water. The 'winner' may receive a prize (e.g. community asset).
Super saver	A competition between households within a community to save the most water, with the 'winner' receiving recognition and/or a prize.
Transparent charging	Fairness is seen as important, with consumers potentially happy for services to be priced in a way that is fair to all. Option could involve development of transparent allocation rules perceived as fair, and tariff increases explicitly aimed at achieving 'fairness' across all charge payers. Likely to be most successful where utilities are trusted, publicly owned or perceived as providing public goods.
Trading	People are motivated by their position relative to others. Provide customers with an allowance of water and, if they use more/less than this, they are allowed to buy/sell additional amounts through a trading platform.
Rebates	Monetary rebates for implementing demand management measures. Likely to have limited effectiveness due to low price elasticity of water demand.
Broader context	People are bad at computation when making decisions, for example **they** put undue weight on recent events and too little on far-off ones. Option could therefore highlight benefit of reducing demand in terms of mitigating recent, imminent or nearby water supply concerns, rather than more abstract or long-term impacts of climate change.

2.4. Stakeholder engagement

A stakeholder consultation exercise was carried out for this project. Initially, four questions were emailed by the project team to 38 people identified as relevant and representative contacts. The questions were:

1. What level of consumption (e.g. per person per day) could be achieved in 50 years' time?

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

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

4. What do you think are the barriers to achieving this (considering the same topic areas as Q3)?

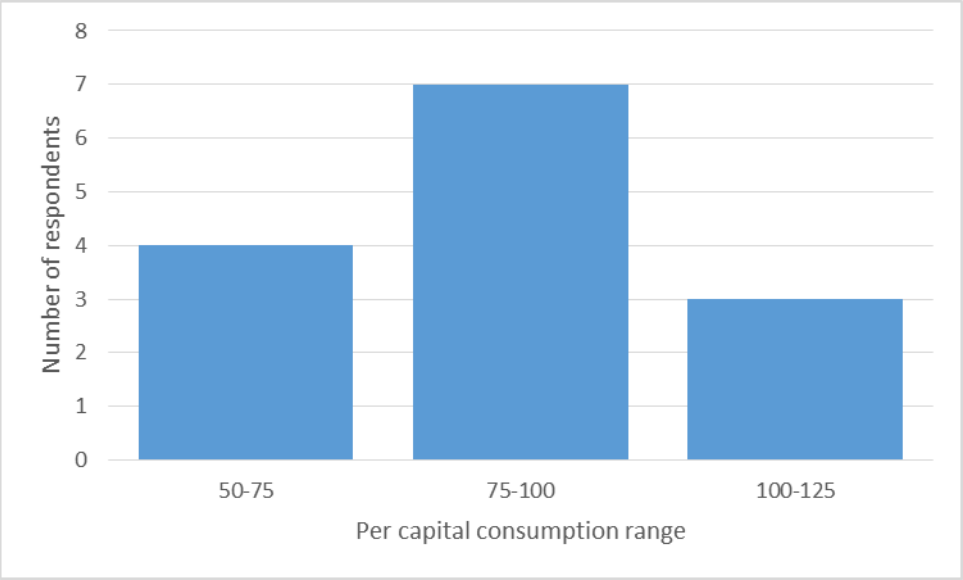
Twenty-five responses were provided representing 23 of the 38 stakeholder organisations contacted (two responses were compiled by colleagues in the same organisations).

The responses from stakeholders provided a valuable insight into the views of sector experts, as summarised in the following sections.

1. What level of consumption (e.g. per person per day) could be achieved in 50 years' time?

Figure 1 is a histogram of responses to question 1, where respondents provided a figure (14 out of 23). It indicates that most respondents thought that a consumption rate less than 100 litres per head per day was achievable possible in the next fifty years.

Figure 1 Stakeholder PCC aspirations 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. 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; regulators, NGOs and water companies 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'.

Selected respondent quotes:

"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."

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

There is general agreement for need fundamental change in social attitudes to water and for the positive role that changing regulation and legislation can contribute. One respondent (supported by the majority) was adamant that the "number one thing" to instigate is a mandatory labelling system to predominate water efficient products availability and use. This is followed (again extensively mentioned in the respondent feedback) by overcoming the challenge of increasing the profile in society of changing the current level of water resource/efficiency awareness embedded within the population (water users). Respondents agree that water resource and potential scarcity is underplayed and that people don't have sufficient understanding on the current state of water resources or the need to save water. 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").

Respondents overwhelmingly identified the need for a sustained, long-term national campaign to increase awareness of water in the environment and the need for a water efficiency. This vision of a national campaign is wider than water companies and other groups were cited - to incorporate that awareness to builders, developers etc. Some mention was made of "water neutrality" (which was in vogue 8 to 10 years ago); the collective society and better understanding of the value of water environmentally, socially, politically and economically. Technology is mentioned; particularly 'smart metering' was directly mentioned by three respondents.

Selected respondent quotes:

"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."

2. 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 efficiency 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; need building regulations and water appliances/fittings need to be minimum standards (one mentioned akin to banning inefficient light bulbs).

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 could learn lessons from the energy smart meter at roll-out.

In summary the main enablers mentioned by respondents included; implementation of higher water efficiency standards and building regulations for new buildings; targeted retro-fitting of existing properties to reduce consumption (Water Neutrality); mandatory water labelling scheme (similar or combined with the energy label); increased metering and smart metering with the potential for smart tariffs (relies on metering).

Selected respondent quotes:

"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. What do you think are the barriers to achieving this (considering the same topic areas as Q3)?

The respondents identified two main barriers - people's lack of interest in water (unless there is a drought) and a perceived reluctance to legislate or regulate in the area of building regulation, water regulations and water labelling. There is scepticism that voluntary schemes would have any significant impact; and it is the case that energy efficiency labelling is compulsory (see reference Energy Saving Trust Briefing Note, July 2017).

Two aspects of the water company regulation process were presented as potential barriers - first is a mindset within companies that a call for water use restraint is perceived as a water supply 'failure' and the fear of penalisation under current regulatory schemes. This hampers honesty and candid transparent communication with customers. 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 companies argue that the price review framework which incentivises them to compete against each other on PCC is not conducive to joint working/ sharing of evidence and the coordination of water saving campaigns; and where cost uncertainties can be a barrier to any measures - one respondent mentioned that WRMPs largely rely on demand management measures over the early years of their plans to meet deficits (and as an aside..."because it is cheaper"), rather than supporting a long term vision of water saving and demand management.

In summary, barriers identified by the respondents to developing initiatives to ensure improved water efficiency in the future include: little conviction that Government will act; lack of a national holistic long-term thinking, fragmented responsibilities, short term regulation with the water industry (despite the rhetoric to the contrary), and the lack of widespread collaborative solutions beyond the water companies involving other organisations such as local government.

Selected respondent quotes:

"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?"

2.5. Patent search

The following patent search was completed using Espacenet[3], which contains worldwide records on patents dating back to 1836. A total of 41 patents were identified in the search. This section includes a summary of the 12 most relevant.

Title: Design and Process to Collect Urban Storm Drainage for Commercial and Residential Use
Date: 2017-11-23
Inventor: MAJERSKY GREGORY MICHAEL
Application Number: US201615157386 20160517
Summary: A process and method of collecting, storing and utilizing the water that enters urban storm drainage systems for the purpose of utilization and reuse. In other cities, average annual precipitation that enters the urban storm drainage system of many cities provides at least half of the combined annual average of potable and industrial water needs.
Available at:
https://worldwide.espacenet.com/publicationDetails/biblio?DB=EPODOC&II=2&ND=3&adjacent=true&locale=en_EP&FT=D&date=20171123&CC=US&NR=2017335549A1&KC=A1

Title: Multifunctional system for rainwater infiltration, collection and storage and purification of sponge city
Date: 2016-06-01
Inventor: HAN JIANGANG; FAN DIWU; ZHU YONGLI
Application Number: CN20161149617 20160316
Summary: The system can be used in residential areas, schools, parking lots, parks and roads, not only can rainwater be stored, but also the content of pollutants such as nitrogen, phosphorus and heavy metal can be reduced, the purpose of recycling is achieved, city water logging is effectively relieved, and the rainwater use efficiency is improved.
Available at:
https://worldwide.espacenet.com/publicationDetails/biblio?DB=EPODOC&II=32&ND=3&adjacent=true&locale=en_EP&FT=D&date=20160601&CC=CN&NR=105625549A&KC=A

Title: A SYSTEM AND A METHOD FOR OPTIMIZING THE USAGE OF WATER AND OTHER RESOURCES IN RESIDENTIAL AND COMMERCIAL APPLICATIONS
Date: 2017-03-16
Inventor: RACHAPUDI VAMSI KRISHNA [IN]; RACHAPUDI HARA GOPALA RAU [IN]; EYUNNI KARAN KUMAR
Application Number: WO2016IB55379 20160909
Summary: The proposed system uses a timed control for regulating the usage of water and other resources used for cleaning, washing and shower purposes. The system is suitable for residential or commercial applications wherein optimization in usage of water and other resources is desired.
Available at:
https://worldwide.espacenet.com/publicationDetails/biblio?DB=EPODOC&II=18&ND=3&adjacent=true&locale=en_EP&FT=D&date=20170316&CC=WO&NR=2017042724A1&KC=A1

Title: Household energy-saving and consumption-reducing system

[3] https://worldwide.espacenet.com/advancedSearch?locale=en_EP

Date: 2017-09-26
Inventor: WANG GUOBAO
Application Number: CN20171611899 20170725
Summary: The system comprises a power supply, an automatic switching device, a night time mode and a daytime mode, a timing device, an automatic energy saving device, an automatic water saving device and a natural gas alarming device. By adopting the mode the system has the advantages that energy consumption of water and electricity can be reduced within the time set by a resident in a daytime or night time mode under different conditions.
Available at:
https://worldwide.espacenet.com/publicationDetails/biblio?DB=EPODOC&II=8&ND=3&adjacent=true&locale=en_EP&FT=D&date=20170926&CC=CN&NR=107203131A&KC=A

Title: SMART WATER SHUT OFF
Date: 2016-04-28
Inventor: ROHLING STEPHEN J [CA]; TARNASKY ROY A [CA]
Application Number: CA20162918952 20160125
Summary: The Smart Water Shut Off system can be installed in either a residential or commercial application to conserve water. It is designed to monitor, give warnings for over consumption and waste occurrences, secondly shut off the water supply in case of pipe bursts; ruptures - whether someone is home or not.
Available at:
https://worldwide.espacenet.com/publicationDetails/biblio?DB=EPODOC&II=4&ND=3&adjacent=true&locale=en_EP&FT=D&date=20160428&CC=CA&NR=2918952A1&KC=A1

Title: Solar waterless washing machine
Date: 2016-03-02
Inventor: ZHANG KEHUA
Application Number: CN20141406556 20140819
Summary: According to the invention, by use of the static dust removing technology and centrifugal treatment processing technology, clothes can be cleaned without water, so energy consumption and pollution are reduced.
Available at:
https://worldwide.espacenet.com/publicationDetails/biblio?DB=EPODOC&II=2&ND=3&adjacent=true&locale=en_EP&FT=D&date=20160302&CC=CN&NR=105369557A&KC=A

There are currently also several other waterless washing machine designs:

- https://worldwide.espacenet.com/publicationDetails/biblio?DB=EPODOC&II=3&ND=3&adjacent=true&locale=en_EP&FT=D&date=20151118&CC=CN&NR=105063960A&KC=A
- https://worldwide.espacenet.com/publicationDetails/biblio?DB=EPODOC&II=4&ND=3&adjacent=true&locale=en_EP&FT=D&date=20110216&CC=CN&NR=201746702U&KC=U
- https://worldwide.espacenet.com/publicationDetails/biblio?DB=EPODOC&II=5&ND=3&adjacent=true&locale=en_EP&FT=D&date=20081203&CC=CN&NR=101314913A&KC=A

Title: Water permeable brick prepared from sulfuric acid waste residue and preparation method of water permeable brick
Date: 2017-03-15
Inventor: ZHENG JINXIAN
Application Number: CN20161937024 20161025
Summary: The water permeable brick prepared from the sulfuric acid waste residue is high in strength, high in water permeable performance, antifreeze and skid-resistant, and has high ecological environmental protection performance. The water permeable brick can be widely applied to the buildings such as plazas, urban roads, residential districts and parking lots.
Available at:
https://worldwide.espacenet.com/publicationDetails/biblio?DB=EPODOC&II=17&ND=3&adjacent=true&locale=en_EP&FT=D&date=20170315&CC=CN&NR=106495659A&KC=A

Title: Double-layer water storage rainwater collecting device and method of city road
Date: 2017-06-20
Inventor: ZHANG YANNIAN; YANG SEN +
Application Number: CN2017123765 20170113
Summary: Allows for temporary water storage in and around a city road. The double-layer water storage rainwater collecting device and method has the beneficial effects that the multiple rapid rainwater collecting temporary storage layers can quickly collect and store the rainwater through water permeable holes, so that efficient rainwater utilization and the disaster prevention function are achieved.
Available at:
https://worldwide.espacenet.com/publicationDetails/biblio?DB=EPODOC&II=0&ND=3&adjacent=true&locale=en_EP&FT=D&date=20170620&CC=CN&NR=106868975A&KC=A

Title: Artificial rainfall dust and application method thereof
Date: 2017-07-25
Inventor: YU SHUNHAI
Application Number: CN20171307996 20170504
Summary: The application method comprises the steps that 1, rainfall conditions of clouds near a target area are detected, and the clouds achieving the rainfall conditions are determined; 2, when the clouds achieving the rainfall conditions need to take a journey of 25-35 min to arrive at the air above the target area, an airplane or a rocket gun is used for uniformly spraying the dust to the clouds achieving the rainfall conditions, and then the purpose that the clouds are over the target area when rain falls is achieved
Available at:
https://worldwide.espacenet.com/publicationDetails/biblio?DB=EPODOC&II=4&ND=3&adjacent=true&locale=en_EP&FT=D&date=20170725&CC=CN&NR=106973734A&KC=A

Title: WATER QUALITY DETECTION, SEPARATION AND RECYCLING SYSTEM AND METHOD
Date: 2018-03-01
Inventor: UPADHYAY SHIVANI [US]; UPADHYAY VARUN
Application Number: US201615369377 20161205
Summary: Separated clean water is stored and recycled for agriculture and toilet purposes resulting in up to 40% reduction in residential and commercial water consumption.
Available at:
https://worldwide.espacenet.com/publicationDetails/biblio?DB=EPODOC&II=0&ND=3&adjacent=true&locale=en_EP&FT=D&date=20180301&CC=US&NR=2018057379A1&KC=A1

Title: High-rise building pipe waste water generating set
Date: 2015-05-20
Inventor: XU WENCHAO; ZHANG YAYUN; WU ZIHENG; JIN YA; YU TENGFEI; CHENG JIANGFENG
Application Number: CN20142852583U 20141229
Summary: According to the high-rise building pipe waste water generating set, the cylinder magnet cuts the magnetic induction line to generate electricity, gas drives an impeller to rotate to generate electricity, and the generating efficiency is high; energy is saved, the environment is protected, and the high-rise building pipe waste water generating set can be widely applied to residential buildings and the like.
Available at:
https://worldwide.espacenet.com/publicationDetails/biblio?DB=EPODOC&II=48&ND=3&adjacent=true&locale=en_EP&FT=D&date=20150520&CC=CN&NR=204344176U&KC=U

Title: APPARATUS FOR ACOUSTIC MONITORING OF PIPELINE CONNECTED COMPONENTS
Date: 2017-11-30
Inventor: WAYMAN MALCOLM
Application Number: WO2017GB51505 20170526
Summary: The method and apparatus allows the detection of the change of condition of the pipeline to be monitored as the operation of the component is performed and compares the live data with predetermined

data to determine whether this change in condition of the pipeline is within acceptable limits and, if not, indicates an alert to cause the operation of the component to be altered.

Available at:
https://worldwide.espacenet.com/publicationDetails/biblio?DB=EPODOC&II=5&ND=3&adjacent=true&locale=en_EP&FT=D&date=20171130&CC=WO&NR=2017203279A1&KC=A1

2.6. Energy efficiency

The 'Dynamics of Energy Mobility and Demand' (DEMAND) Centre at Lancaster University is a leader in research and ideas on end-use energy management. The research they undertake recognises that energy is not used for its own sake but as part of accomplishing social practices at home, at work and in moving around. In essence the centre focuses on what energy is for rather than how it is produced.

There are clear parallels here with water and much of their research and thinking could be applied to the end uses of water. The remainder of this section provides a commentary on the key themes in the DEMAND centres discussion points, with regard to water use and the potential measures (either technological or behavioural) that could be used to deliver deep reductions in consumption.

Much water use is driven by 'behaviour', made up of social, cultural, technological interactions within homes and communities. Domestic household demand cannot be understood in isolation from what people do with water, and 'why' these patterns occur due to cultural norms and conventions linked to the practice (e.g., cultures of cleanliness) as well as histories of technologies and infrastructures (e.g., how everyday showering co-evolved with the uptake of showering technologies in homes in the UK).

Strategies for reducing water need to focus on the services that are made possible by this consumption, for example the freshness from a morning shower, relaxation from an evening bath or a green and vibrant lawn that results from garden watering.

Water use is made possible by the technology and infrastructure that provides potable water to multiple points around a modern house. Developments in technology change the way we use water (e.g. increased rates of showering due to plumbing and hot water heating technology) and these changes become embedded in homes (e.g. via *en-suite* bathrooms and wet rooms).

The provision and daily use of showers appear to be the new normal (even though showers remained uncommon in UK households until about 40-50 years ago). As a result we (on average) use more water for personal washing via our daily shower, than we did in the past in our less frequent (but larger volume) baths. This begs the question how will the popularity of showers change in the future? Will something else replace them?

The DEMAND Centre identifies the need for "radical reconfiguration of the practices that call for energy…", in order to reduce energy demand and the same call could be made to reduce the demand for water. Whilst some reductions in water use can be made using technology, such as toilets with lower flush volumes, behaviour change needs to address the fundamental practices that drive water use. The DEMAND Centre emphasises this using "theories of 'individual attitude, behaviour and choice (known as the ABC). This locates both the problem and the response as a matter of consumer behaviour and downplays the extent to which the state and other institutions sustain unsustainable conventions and ways of life and have a hand in structuring present and future options and possibilities."

This makes long-term fundamental change challenging: controlling or predicting how individuals respond to policy initiatives is very difficult. Behavioural science has been shown to have some short-term success but such measured need to be maintained constantly over a long period of time.

And it isn't just about influencing behaviour alone, as this is part of the complex web of interactions that shape how we use water. As the DEMAND Centre states: "An effective intervention in social processes modifies

shared conventions, redefines normality, and modifies cues and codes of everyday life. In thinking about what this involves a first step is to recognize that technologies, standards and infrastructures of supply do not simply meet existing needs: they shape future practices and the demands that follow."

This view poses difficult questions for policy makers and other stakeholders: who are we to tell people how to use water in their own homes (or what type of water to use)?

A long term policy for reducing water demand needs to be joined-up with other sustainable water management policies, such as the control of surface water runoff and pollution control. It also should links with policies across government, including in particular the Ministry for Housing Communities and Local Government, which has a significant influence via Building Regulations. Other stakeholders, particularly manufacturers and retailers of water using devices also have an important role to play.

3. Results and analysis

The final list of response measures is shown in Table 3. Each response measure is categorised into a type of response. Each response measure has been scored in two ways:

a) Firstly, each response measure is scored by the estimated number of years until it becomes widely used in society. This is based on expert judgements by the project team, assuming that there are mechanisms in place to promote, fund, encourage and deliver the measure. The judgements tended to err on the side of caution. For example, the first measure in the table is "Eco-branding of WE devices"; whilst labelling is currently available, and it is not used consistently across all devices and outlets. We are also aware the industry is about to carry put research on mandated labelling schemes, therefore we have scored this measure at 8 years until in widespread use.

b) Secondly, each measure is given a score based on the potential average water saving or water efficiency benefit in units of litres/property/day. This is based on published evidence[4,5], web searches, product literature, or on the proportion of household consumption for that device from micro-components, see Figure 2. Where micro-component proportions are used, the relationship between the micro-component and the end-use was derived from the proportions in Figure 3.

We have represented the analysis of the response measures graphically in Figure 4.

[4] Water efficiency evidence base statistical analysis, Water Industry Collaborative Fund, June 2015.
[5] http://www.waterwise.org.uk/water-efficiency-database/

Figure 2 Proportions of household micro-component water use

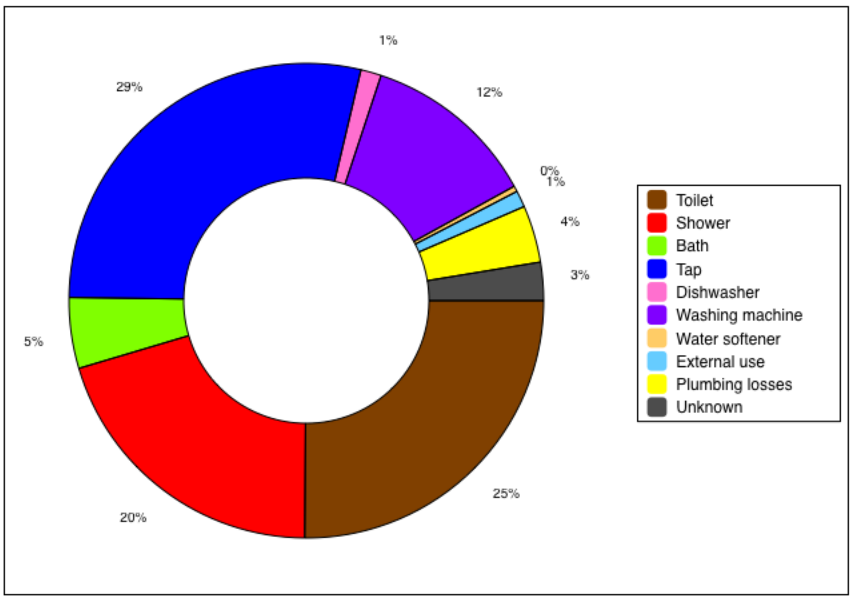


Figure 3 The relationship between household use, micro-components, end use and macro-components

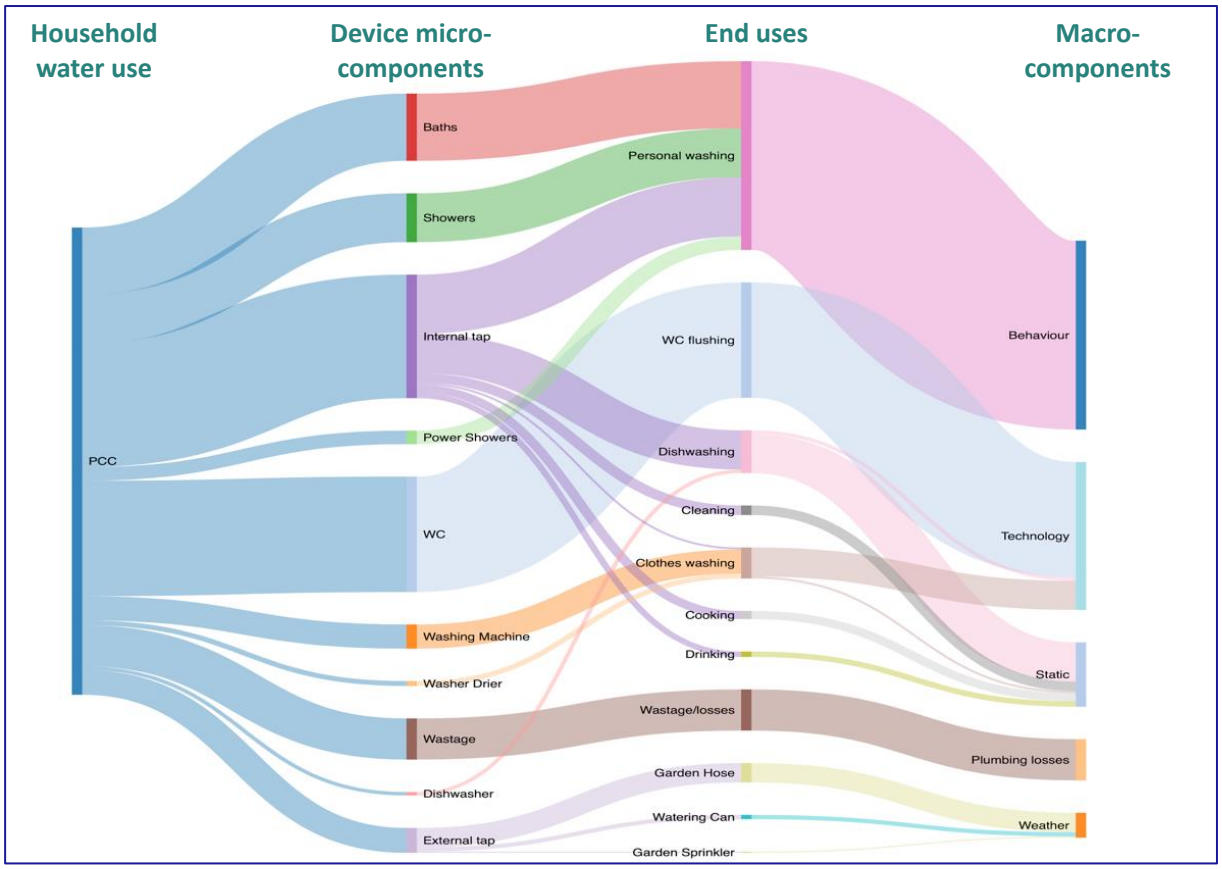


Figure 4 Showing the measures for reductions in household water demand and potential impact in terms of water saving and time to widespread delivery

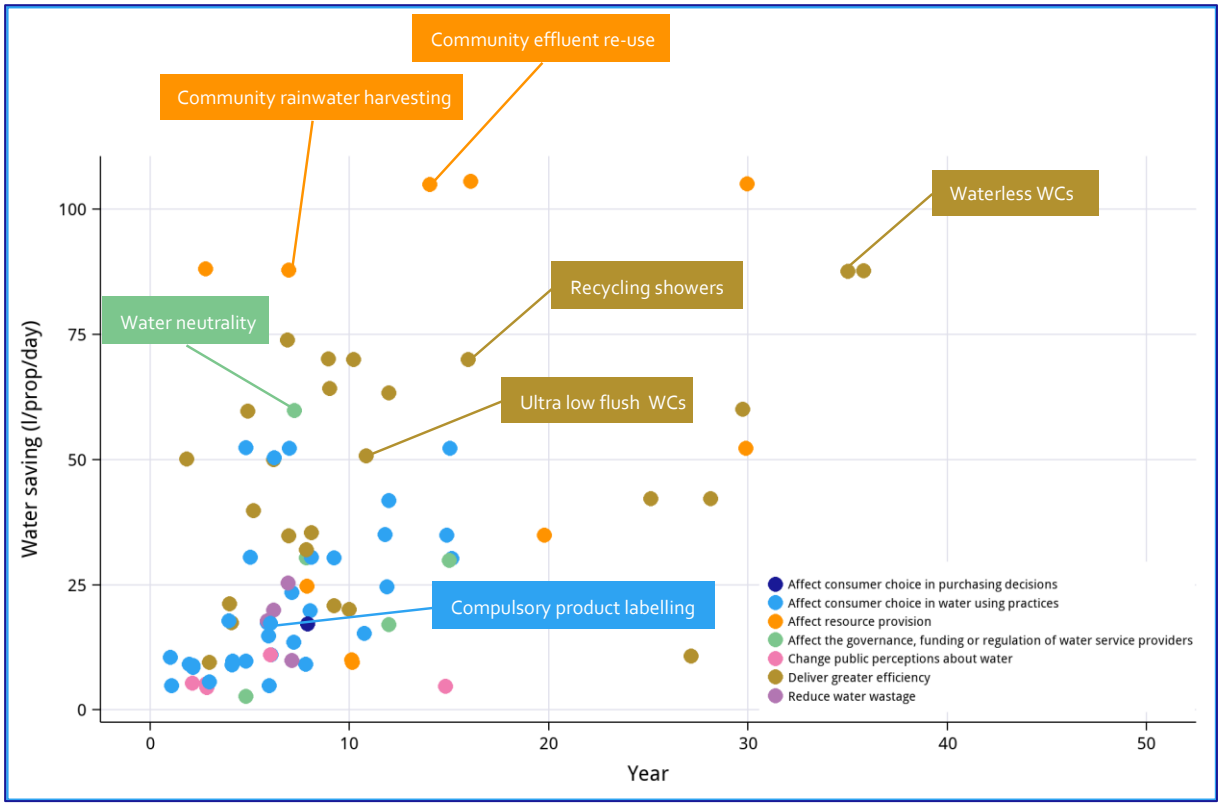


Table 3 Full list of household consumption response measures

Type of response	Specific response measure	Estimated years to widespread use	Potential water efficiency benefit (l/prop/day)
Affect consumer choice in purchasing decisions	Eco-branding of WE devices	8	17.5
Affect consumer choice in water using practices	Water saving tips	1	10
Affect consumer choice in water using practices	WEFF device distribution	1	5
Affect consumer choice in water using practices	Home water reports - bespoke WE info	2	8.75
Affect consumer choice in water using practices	Setting a goal/making a pledge - could include rewards/penalties	2	8.75
Affect consumer choice in water using practices	Target shorter showers for adolescents	2	9.1
Affect consumer choice in water using practices	Meter customers with a boundary box	3	5.25
Affect consumer choice in water using practices	Point of purchase advice	4	17.5
Affect consumer choice in water using practices	Rebates for implementing WE	4	10
Affect consumer choice in water using practices	Value of water - monetary benefit for water savings	4	8.75
Affect consumer choice in water using practices	Enhanced FMO and other metering options	5	52.5
Affect consumer choice in water using practices	Interest-free loans for WE devices	5	30
Affect consumer choice in water using practices	Social norms and feedback	5	10
Affect consumer choice in water using practices	Gamification - rewards, incentives, etc	6	17.5
Affect consumer choice in water using practices	Rebates for low flow appliances	6	15
Affect consumer choice in water using practices	Seasonal tariffs	6	10.5
Affect consumer choice in water using practices	Smart water bills	6	5
Affect consumer choice in water using practices	Targeting via segmentation	6	50
Affect consumer choice in water using practices	Tariffs	6	17.5
Affect consumer choice in water using practices	Community competition to save water	7	23.45
Affect consumer choice in water using practices	Targeted accelerated metering programme with 'persuaded optants' (Progressive metering)	7	52.5
Affect consumer choice in water using practices	Water performance certificates	7	14
Affect consumer choice in water using practices	Behavioural science for internal leakage and WEFF	8	20
Affect consumer choice in water using practices	Customer app for behaviour change	8	30

Type of response	Specific response measure	Estimated years to widespread use	Potential water efficiency benefit (l/prop/day)
Affect consumer choice in water using practices	Water lottery - prizes for staying within allowance	8	8.75
Affect consumer choice in water using practices	Personalised consumption data - Watersmart	9	30
Affect consumer choice in water using practices	Water contracts like mobile phones	11	15
Affect consumer choice in water using practices	Financial incentives for reduction by 10%	12	35
Affect consumer choice in water using practices	Green Deal type offers (Energiesprong)	12	42
Affect consumer choice in water using practices	Time of use pricing	12	24.5
Affect consumer choice in water using practices	Automatic enrolment in WE progs	15	30
Affect consumer choice in water using practices	Penalty charge - beyond daily allowance	15	35
Affect consumer choice in water using practices	Universal metering	15	52.5
Affect resource provision	Increased competition for water resources	3	87.5
Affect resource provision	Community level rainwater harvesting	7	87.5
Affect resource provision	Greywater for irrigation	8	24.5
Affect resource provision	Tiles and other structures for rainwater storage	10	10
Affect resource provision	Water storage ground tiles or bricks	10	10
Affect resource provision	Grey water reuse	14	105
Affect resource provision	Non-potable sources for new developments	16	105
Affect resource provision	Storing water under roads	20	35
Affect resource provision	City level rainwater collection storage and treatment (sponge cities)	30	52.5
Affect resource provision	Greywater mandatory for all new homes	30	105
Affect the governance, funding or regulation of water service providers	Transparent charging - fairness for all charge payers	5	3
Affect the governance, funding or regulation of water service providers	Water neutrality for new developments	7	60
Affect the governance, funding or regulation of water service providers	Water efficiency regulations	8	30
Affect the governance, funding or regulation of water service providers	Permanent non-essential use bans	12	17.5

Type of response	Specific response measure	Estimated years to widespread use	Potential water efficiency benefit (l/prop/day)
Affect the governance, funding or regulation of water service providers	Trading - buy/sell water allowances	15	30
Change public perceptions about water	Schools education programme	2	5
Change public perceptions about water	Broader context (highlight link to imminent or nearby water supply concerns)	3	5
Change public perceptions about water	Community outreach	3	5
Change public perceptions about water	Natural capital accounting	6	10.5
Change public perceptions about water	Increase in green infrastructure	15	5
Deliver greater efficiency	smarter home visits (ongoing)	2	50
Deliver greater efficiency	Target water consumption in university accommodation	3	9.1
Deliver greater efficiency	Dumb to smart meter replacement programme	4	21
Deliver greater efficiency	Smart irrigation systems (e.g. based on SMD)	4	17.5
Deliver greater efficiency	Advice to housebuilders on high WEFF spec	5	60
Deliver greater efficiency	Fixing leaking toilets	5	40
Deliver greater efficiency	housing association 'fix'	6	50
Deliver greater efficiency	Internet of things	7	35
Deliver greater efficiency	Smart meter with information feedback for households	7	73.5
Deliver greater efficiency	Volume limiting baths and showers	8	31.5
Deliver greater efficiency	Water demand in planning process	8	35
Deliver greater efficiency	New provision models - Miele bundles	9	21
Deliver greater efficiency	Point of use treatment	9	70
Deliver greater efficiency	Recycling showers	9	63.7
Deliver greater efficiency	Smart homes and infrastructure	10	70
Deliver greater efficiency	Smart taps	10	19.6
Deliver greater efficiency	Ultra-low flush WC	11	51.0
Deliver greater efficiency	Smart- digital showers	12	63.7
Deliver greater efficiency	Smart toilets	16	70

Type of response	Specific response measure	Estimated years to widespread use	Potential water efficiency benefit (l/prop/day)
Deliver greater efficiency	Waterless washing machine	25	42
Deliver greater efficiency	Waterless dishwashers	27	10.5
Deliver greater efficiency	Filtration using graphene sheets as membrane	30	60
Deliver greater efficiency	Waterless WCs	40	87.5
Deliver greater efficiency	Collect water from in-house condensation	45	87.5
Reduce water wastage	Leak detection and auto shut off	6	17.5
Reduce water wastage	Low cost sensors for flow control/smart fittings	6	20
Reduce water wastage	Apps to control water use and appliances	7	25
Reduce water wastage	Remote controlled valves to limit water use by volume or time	7	10