A Framework for Improving Domestic Water Conservation in Ireland

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Report produced for An Fóram Uisce, November 2021

Lead Author: Dr Sarah Cotterill, University College Dublin

Supporting Author: Dr Peter Melville-Shreeve, University of Exeter

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Executive Summary

In recent years, Ireland has experienced shortages in households' water supply. Water shortages are expected to become increasingly occurrent due to population growth, changes to rainfall patterns with climate change, along with other socio-economic factors. Efforts to conserve water are likely to become increasingly important across both commercial and domestic sectors. In 2017, the Joint Oireachtas Committee on the Future Funding of Domestic Water Services recommended that conservation of water resources should be embedded as a principle of water policy in Ireland, encouraged by incentivising savings and discouraging wastage. However, there remains a need to identify how water conservation measures can be implemented in Ireland, and how they may relate to national and EU legislation, such as building standards and regulations. Current building regulations provide guidance on selected water conservation measures, but it remains at the discretion of the owner whether or not to incorporate them. This report was produced for An Fóram Uisce in response to an Open Research Call on "*A Framework for Improving Domestic Water Conservation in Ireland*" launched in April 2021. An Fóram Uisce sought proposals from the research community to explore the mechanisms needed to best encourage and facilitate domestic water conservation measures in Ireland, focusing specifically on available technology in domestic water conservation, related national and EU legislation, water efficiency labelling, water conservation incentives and education and awareness campaigns. The work investigating these five themes was bound by time and budgetary constraints as specified in the research tender. Meeting this brief lead to the formation of the five Work Packages included in this report.

1. Available Technology in Domestic Water Conservation

Work Package 1 is a review of national and international literature relating to technologies available for domestic water conservation. The technologies have been categorised by micro-component, end-use and method of implementation, and evaluated in terms of their potential water savings, their technology readiness level and other considerations such as cost and ease of integration. The specific products presented for each technology are given as examples only. The inclusion of a particular manufacturer is not an endorsement. Technologies have been identified, ranging from simple tap aerators to recycling showers, which are individually able to save between 20 – 100 litres/property/day, equating to a 5 – 15% reduction in household water use. If these products are used concurrently, there is considerable potential to drive demand significantly below 100 litres/person/day, achieving a greater than 25% reduction in demand. Greywater reuse or community-level rainwater harvesting could deliver some of the most significant savings (of up to 39 litres/person/day, or 100 litres/property/day), particularly if grey/rainwater is reused for toilet flushing, outside use and clothes washing, and/or if implemented in multi-occupancy buildings. Barriers to the implementation of water-saving technologies include: (i) the cost of purchasing, installing and operating such technologies, (ii) the market availability of such technologies in Ireland; and (iii) customer preference for higher consuming products. Unless there are policy and regulatory drivers, economic incentives and effective awareness campaigns, the uptake of technologies may be limited. It is also noted that uptake of technology does not guarantee continued maintenance or operation when management and maintenance arrangements are not incorporated.

2. Legislation Related to Water Conservation

Work Package 2 reviews live and historic regulation and policy within Ireland and the EU including the Water Framework Directive, the Household Water Conservation Charge, the Water Services Act, Future Funding of Domestic Water Services, Irish Water's Code of

Practice for Water Infrastructure and the Water Conservation Grant, amongst others. The multiple benefits of water conservation are best realised when a systems-thinking approach is taken. The implementation of water conservation measures has the potential to: (i) contribute to net zero carbon targets; (ii) reduce supply risks when meeting future development targets outlined in Project Ireland 2040; and (iii) reduce wastewater flows, and consequently the environmental impact which arises from a lack of capacity in sewers and wastewater treatment plants. Drawing on a case study from the UK, the concept of water neutrality – i.e. the notion that new developments should not increase the demand for water above the level required prior to development - is proposed as an option for mitigating concerns over levels of abstraction, the sustainability of supply in areas of water scarcity, or lack of capacity in the sewer network; enabling planned development to continue to meet projected growth. Mechanisms to improve the implementation of water conservation strategies are identified from international best practice. This includes greater integration of water and energy efficiency policy; minimum standards for appliances, fittings and products; and specified targets for per capita consumption in the building regulations.

3. Water Efficiency Labelling

Work Package 3 provides an overview of best practice in water efficiency labelling, drawing from international examples including the Australian Government's Water Rating, the US EPA's WaterSense label, the Singapore Water Efficiency Labelling Scheme, and the European Water Label. The introduction of a mandatory water label could contribute to changes to consumer preference for efficient devices, product innovation on fittings and appliances, and reductions in per capita consumption. In Singapore, following the introduction of a mandatory water label, sales of efficient (3-tick) washing machines increased by 51% in 5 years; the rating system was updated to introduce a fourth tick due to an increase in the amount of efficient appliances in the market, and there was a reduction in per capita consumption across this time period. The recent intention to introduce a mandatory, government-led label in the UK is provided as a benchmark. A 2019 review of water labelling scheme scenarios by the Energy Saving Trust found that a mandatory, government-led strategy was deemed to be the most cost-effective approach, and was expected to cost less than a third of the cost of implementing an industry-led, voluntary scheme. Furthermore, the potential for water-savings in the mandatory, government-led scheme were expected to be 70% higher than a voluntary, government-led scheme, and 95% higher than a voluntary, industry-led scheme (i.e. the business as usual case). The existence of an industry-led, voluntary labelling scheme in Europe may not preclude the potential to implement a national mandatory scheme. Comparisons with other European labelling schemes suggest there may be potential for Member States to adopt additional national measures concerning mandatory labelling.

4. Water Conservation Incentives

The fourth Work Package reviews monetary and non-monetary incentives for domestic water conservation. Price-based strategies include volumetric water pricing, to incentivise consumers to use less water; and subsidies for water-saving technologies, to encourage the uptake of efficient devices or the use of alternative water sources. Pricing alone is unlikely to be a successful measure to reduce demand. Success is most commonly achieved through the implementation of multiple monetary and non-monetary incentives. However, savings arising from non-price based behavioural change may last longer than those induced by rising prices or taxes, whilst minimising issues of equity and fairness that can limit the social effectiveness of price-based measures. Non-pricing strategies include the use of regulation, targets, restrictions, alternative water sources, water-saving devices and education and awareness campaigns. Restrictions are often effective in the short-term but other measures are required to change behaviour and achieve long-term reductions in demand. The cumulative effect of water-saving devices offers the biggest potential for water conservation, particularly when delivered alongside a sustained and consistent programme of education and awareness. However, there is a lack of current research on water conservation incentives: best practice in this sphere is more than 10 years old. Furthermore, long-term evaluation of the success of such interventions is not widely available. There is therefore a need to conduct further research to quantify the potential water savings that could be achieved from non-pricing strategies; to evaluate the cost-benefit of a comprehensive water conservation campaign in Ireland; and to identify barriers and opportunities to the implementation of non-price based interventions such as water-saving technologies and/or smart metering.

5. Education and Awareness

The final Work Package assesses the measures required in public awareness to support water conservation policy in the absence of volumetric water charges. National and international examples of water conservation awareness campaigns are provided, exploring the success and limitations of the communication strategies used. Campaigns are predominantly employed during short and disruptive crises, such as a drought or other supply interruptions. As a policy strategy, there is typically less public reluctance to informational campaigns and they can lead to a longer and deeper change in behavior than other policy instruments, such as economic or regulatory strategies. However, a key challenge involves addressing systemic barriers in understanding about water. The lack of public awareness around the processes that underpin water treatment and supply, the amount of energy and resources required to produce drinking water, and the amount of water an individual uses hinders attempts to introduce water conservation measures. Furthermore, there are challenges with monitoring the effectiveness of campaigns, as they are often introduced concurrently with other strategies. Campaign effectiveness is typically very location-specific: their success is influenced by the design and intensity of the campaign, as well as contextual information such as seasonality or who is leading the campaign. Whilst campaigns can be deployed more readily and cheaply than other policy instruments, barriers remain that can limit engagement with water conservation. This could include public disinterest, a low public knowledge base, lack of resources for highly-effectual communications, a lack of institutional trust in the authority delivering the messaging, and/or an over-reliance on certain strategies, such as social media.

Recommendations

Recommendations are made to facilitate agencies to engage with water conservation; to strengthen regulation and policy; to support further research and to enhance awareness (Figure 1). Recommendations draw on international best practice, primarily from Australia, Denmark, Singapore, and the United Kingdom. There is a need for sustained Government buy-in to support the following recommendations:

1. Implement a mandatory Government-led water labelling scheme linked to revised building regulations and fittings standards.
2. Update building regulations to specify total water use per building and maximum ratings for appliances, fittings and products.
3. Introduce smart metering as a non-pricing strategy to raise awareness on how and where water is used, providing immediate feedback to the user.
4. Include water use in the BER certificate, creating stronger links between water and energy efficiency at the building scale.
5. Establish a national water conservation team, comprised of all agencies and partners responsible for water, to share best practice, skills and knowledge in Ireland

6. Rethink water education to support a bottom-up understanding of water and link this with the national curriculum. This should include the processes that underpin treatment and supply, the energy and resources required to produce drinking water, and how much we as individuals use.
7. Identify funding mechanisms for retrofittable water-saving kits provided free-of-charge to all domestic households.
8. Explore the multiple benefits of water conservation measures in contributing to net zero carbon targets, Project Ireland 2040 development targets, and in reducing wastewater flows.
9. Facilitate agencies and partners to engage through the delivery of workshops on systems-thinking on water conservation.
10. Support further research into the barriers and opportunities for the implementation of water-saving technologies and smart metering; the cost-benefit of a comprehensive and sustained water conservation education campaign in Ireland; and methods to quantify water savings from non-pricing strategies.

The rationale behind each opportunity is outlined in Figure 2.

Conclusion

This report focuses on integrating and synthesising existing information from the scientific literature, international case studies and policy documents to provide recommendations. Based on the scope of the review, four areas of recommendations are identified, which are underpinned by a need for sustained Government-level buy-in. Financing sustained and consistent domestic water conservation interventions would need to be considered as a long-term policy. The costs of the measures are difficult to calculate with precision. However, a report by the National Infrastructure Commission[1] in England suggested the cost of not 'preparing for a drier Britain' – resulting in a large number of households enduring supply interruption for extended periods of time due to severe drought – could lead to an economic impact in England of £25 – 40 billion. Whilst the magnitude of the cost may not be the same in Ireland, it is worth noting that significant supply interruptions leading to considerable social and economic impact could also occur here, given the current and projected risks to supply. Research in the UK suggests the single most cost-effective intervention to reduce per capita consumption is a mandatory government-led scheme to label water-using products, linked to revised building regulations and standards relating to water supply fittings. Cost-benefit analyses of water labelling schemes in Australia and the UK have demonstrated that the benefits significantly outweigh the costs, and that the value and impact of such schemes is comparatively larger when they are mandatory, government-led and associated with other regulatory mechanisms. Furthermore, the implementation of such schemes has been shown to facilitate other water conservation measures such as increased adoption of efficient technologies and behaviour change. The recommendations made are based on the requirements and specification laid out in An Fóram Uisce's request for tender, and intend to support the adoption of domestic water conservation measures in Ireland to help safeguard future water supplies.

[1] https://nic.org.uk/app/uploads/NIC-Preparing-for-a-Drier-Future-26-April-2018.pdf

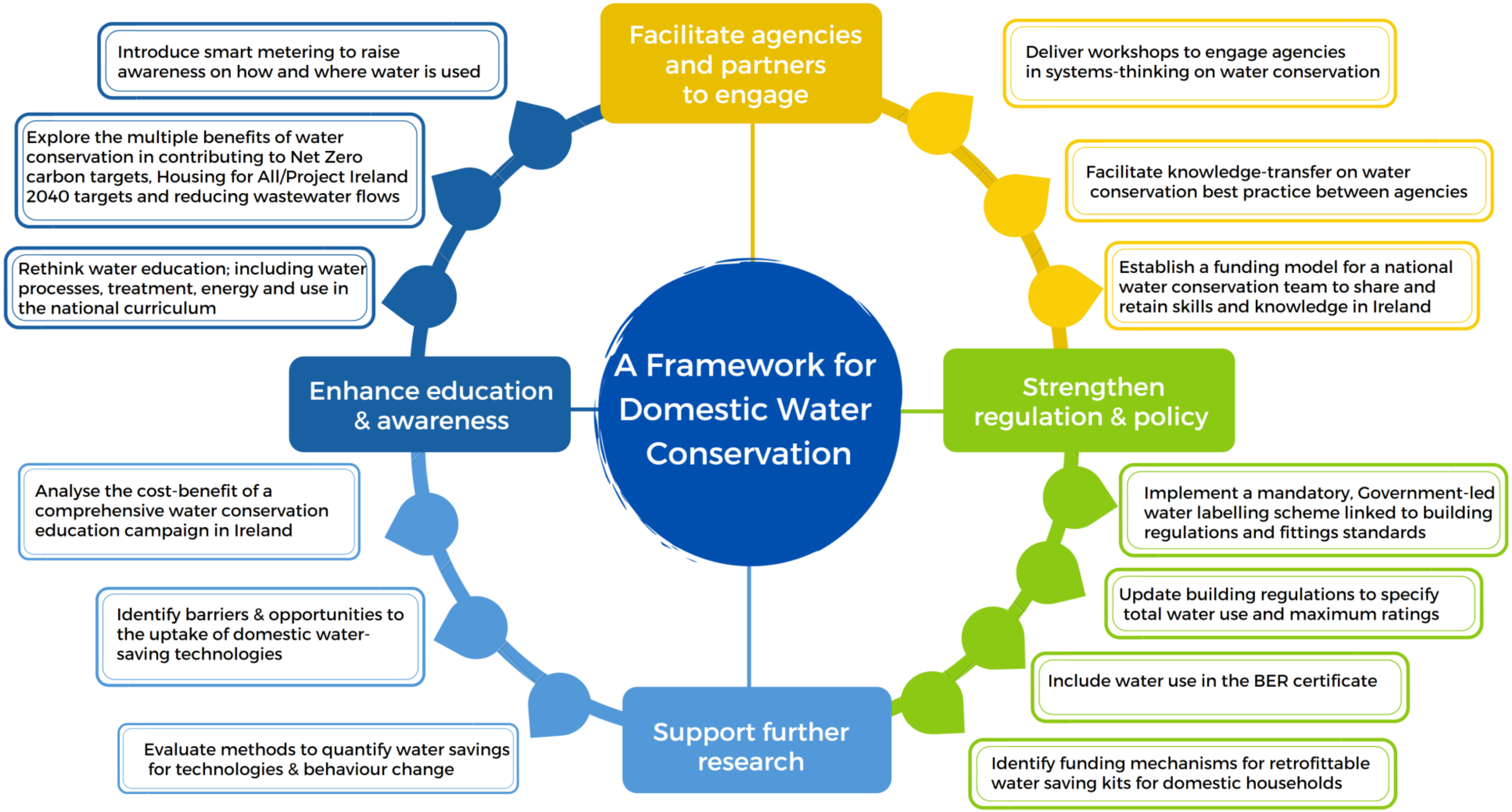

Figure 1 Policy recommendations for domestic water conservation in Ireland

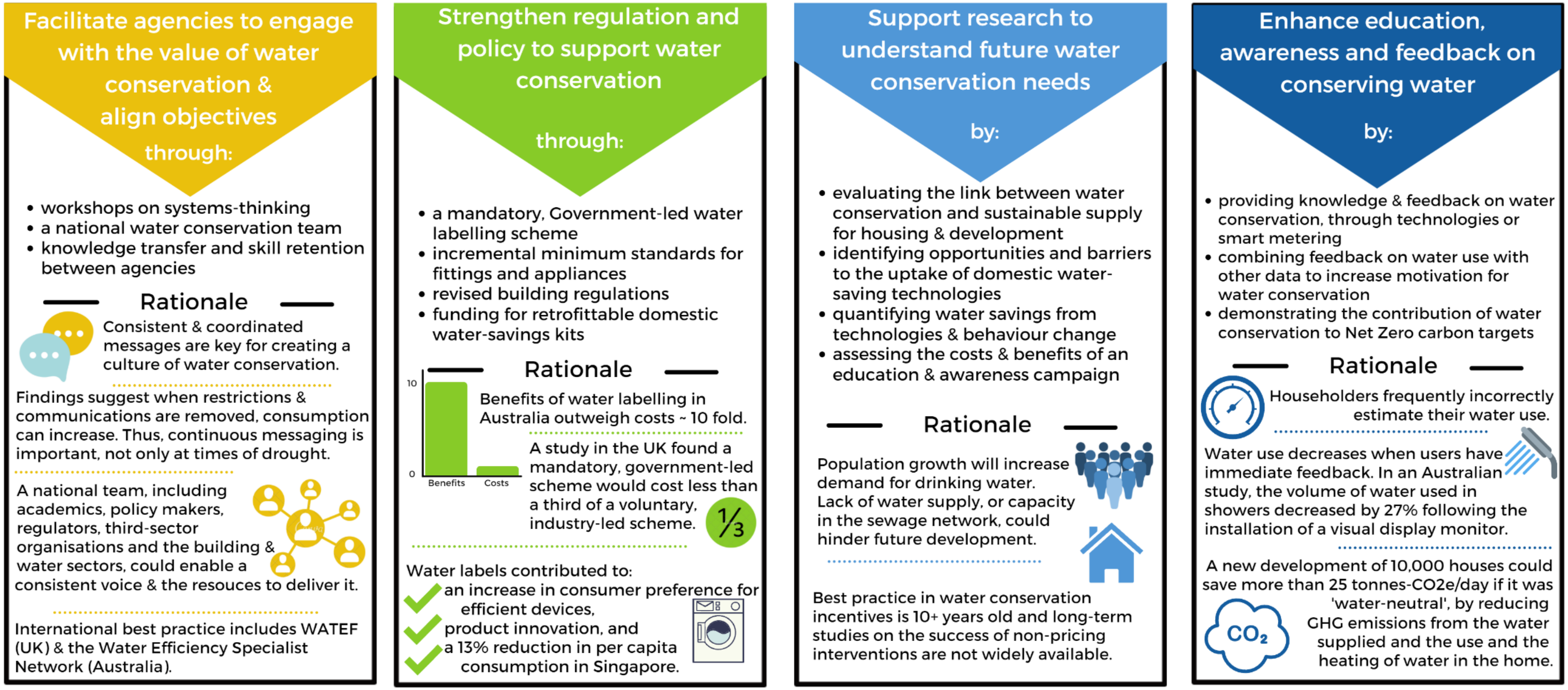

Figure 2 Rational for policy recommendations

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Introduction

Ireland is a relatively wet country. Despite the predominantly wet climate and abundance of water resources, there have been shortages in household water supply in recent years. Water resource availability varies across the country and is under growing pressure from population increase, increasing demand and climate change impacts. The eastern parts of Ireland receive on average a total of 750 – 1000 mm of rainfall a year, the west receives between 1000 – 1400 mm and mountainous regions can exceed 2000 mm a year (Figure 3A) (Met Éireann, n.d.). However, the areas with the lowest rainfall are the most inhabited (Figure 3B). Approximately 2 million people (40% of the population) live within the counties of Dublin, Wicklow, Kildare and Meath – known as the Greater Dublin Area (GDA) and account for a daily potable water demand of nearly 600 million litres/day (Irish Water, 2019a)

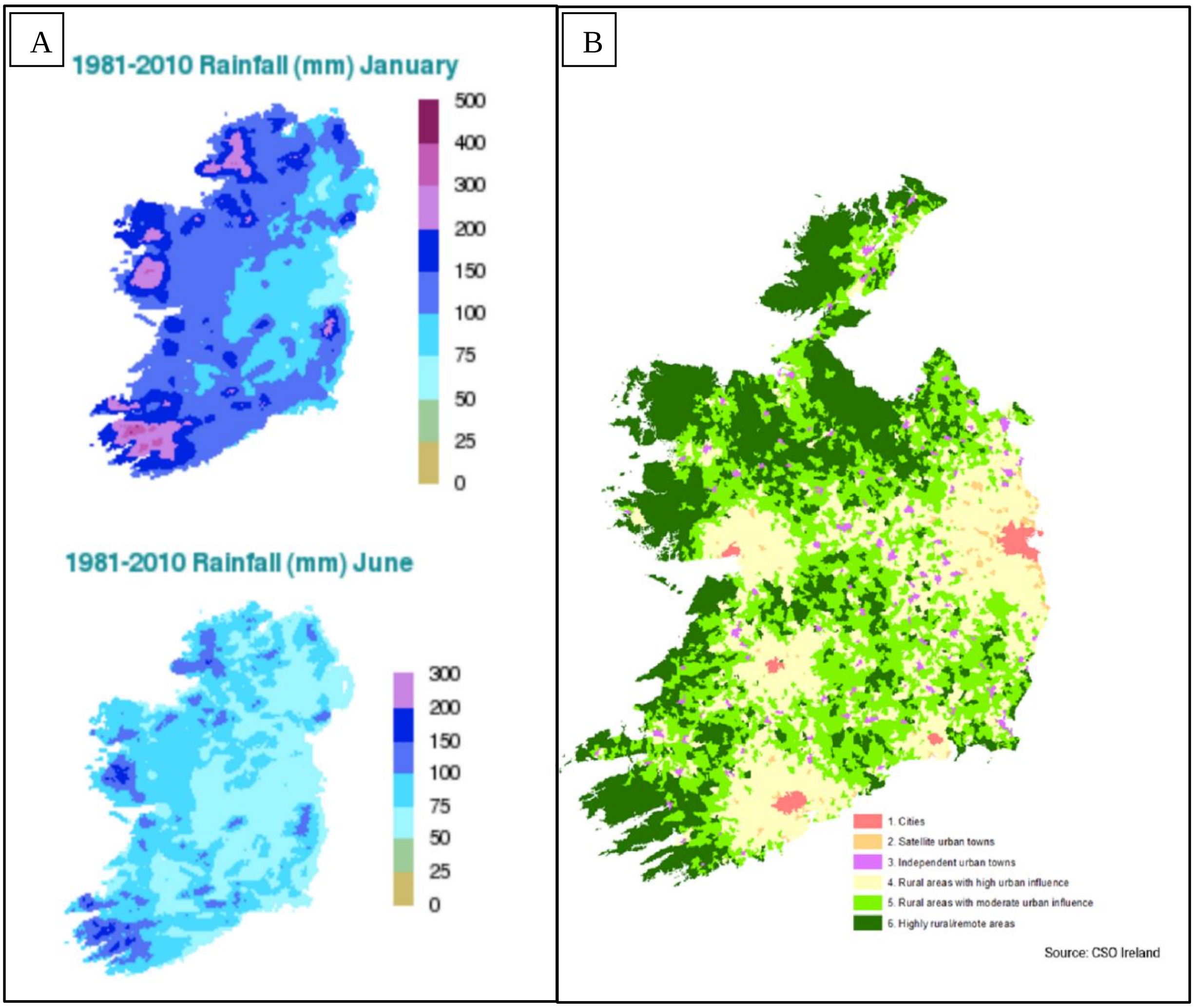


Figure 3 (A) Average monthly rainfall (mm) in January and June between 1981 to 2010 (Met Éireann, n.d.) and (B) population distribution in 2016 (Central Statistics Office, 2019).

Ireland has a disproportionately large number of water supply zones relative to its population size. Irish Water, the country's national water utility, currently abstracts raw water from more than 1000 individual sources and treats it to drinking water standard in 749 Water Treatment Plants (WTPs) (Figure 4). The size of these WTPs varies significantly across the country. The 72 largest WTPs (i.e. less than 10% of all WTPs) produce 73% of the water supplied (Irish Water, 2021). WTPs feed water into supply areas known as Water Resources Zones (WRZs). Each WRZ is an independent water supply system serving a region, city, town or village and is governed by topography or the extent of the water distribution network in an area. There are 539 WRZs in Ireland. These range in size, serving populations of less than 30 people (small rural areas) up to 1.7 million people (Greater Dublin Area - GDA).

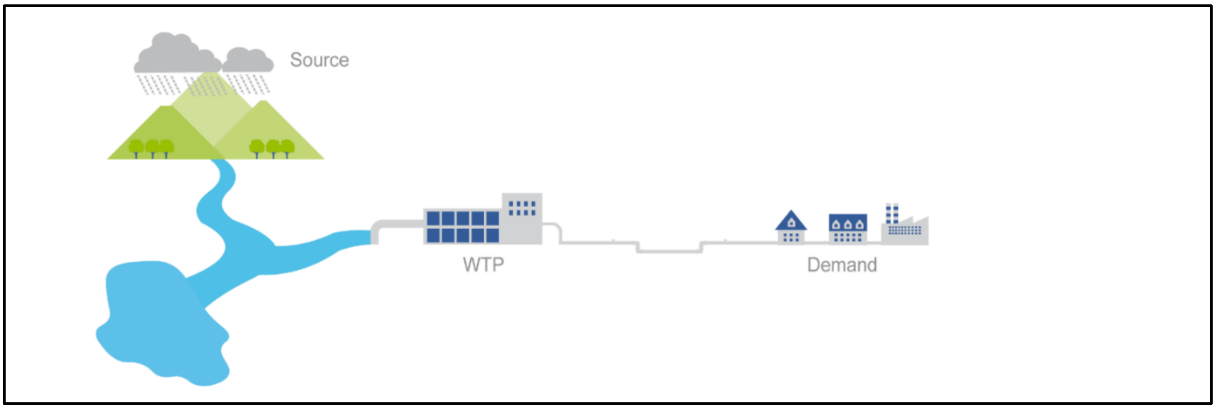


Figure 4 Simplified water supply schematic (Irish Water, 2021).

Irish Water's supply demand balance calculations indicate that 58% of WRZs suffer a supply risk in normal conditions and 66% are in deficit during the Dry Year Critical Peak (equivalent to a summer drought) (Irish Water, 2021). The supply risk in Ireland is larger than the supply-deficit seen in England (which has relatively comparable infrastructure and a reasonably similar climate), where approximately one third of WRZs are expected to have a supply-demand deficit within the next five years (Bunney et al., 2021). The UK Government recently (1 July, 2021) announced the intention to revise legislation to include mandatory water efficiency labelling on all water-using products, and to encourage the adoption of a minimum building standard of 110 litres/person/day in water stressed areas (UK Parliament, 2021). No such legislation exists at present in Ireland. In 2017, the Joint Oireachtas Committee on the Future Funding of Domestic Water Services recommended that conservation of water resources should be embedded as a principle of water policy in Ireland, encouraged by incentivising savings and discouraging wastage. Yet, despite the inclusion of guidance on selected water conservation measures in the Irish building regulations, it remains at the discretion of the owner whether or not to incorporate them and there are no grants available to assist the implementation of water conservation measures.

This is pertinent now, as the frequency of water resource shortages in Ireland is increasing. Dr Arlene Crampsie, from the Irish Drought Project said, "*Drought is an overlooked climate hazard in Ireland, and it is likely that the frequency and severity of droughts in the coming decades will increase*" (Rolston, 2020). Three out of the past four years (2018 – 2021) have involved some level of water conservation requests or restrictions. In 2021, there were water conservation requests and night-time water restrictions in the counties of Donegal, Dublin, Laois, Kerry, Meath, Westmeath, Longford and Wexford. In June 2020, Ireland was the only country in Europe to implement a Water Conservation Order (lasting for six weeks) (European Drought Observatory, 2020) following the driest May on record since 1850 and a 20% increase in domestic water use during the Covid-19 pandemic (RTÉ, 2020). In the summer of 2018 there was a National Water Conservation Order, with night-time pressure restrictions in the Greater Dublin area, implemented to safeguard supply for essential purposes during the drought.

The challenge faced is complex. The current challenges Ireland's water supplies face are likely to become exacerbated as the population is expected to increase by 21% over the next 25 years and forthcoming abstraction legislation (required to ensure Ireland can meet its obligations in the Water Framework Directive) may reduce the amount of water that can be withdrawn from rivers and groundwater aquifers in the future (Irish Water, 2021). Significant change is required to ensure the sustainability of supply despite the compounding challenges of a growing population, a changing climate and shifts in socio-economic patterns, all of which drive up demand. Considerable reductions in the current level of demand are achievable and will be necessary as part of a sustainable water supply for the future.

Efforts to conserve water will become increasingly important across both commercial and domestic sectors. This report focuses solely on household water conservation, based on the specification provided in An Fóram Uisce's request for tender. For the purpose of this report, household water consumption is assumed to be the water flowing into the customers' internal plumbing pipes and includes water consumed, wasted and lost inside the household or from external customer taps. It does not consider any losses in customer supply pipes (i.e. any leakage from the pipe connecting the water main at the property boundary with the customers' internal plumbing) or any losses in the water supply network outside of the property boundary. Whilst there are considerable opportunities for water conservation in the supply network and in commercial sectors, these aspects are out of scope for the study.

The motivation for this study is to provide strategic guidance to An Fóram Uisce (The Irish Water Forum) on what mechanisms are needed to best encourage and facilitate domestic water conservation measures in the light of future population growth, a changing climate and differing social values associated with water. An Fóram Uisce's request for tender specified five areas to be addressed within the report. The requirements of the report, as described in the tender, included:

(1) Available technology in domestic water conservation

- Highlighting international best practice in innovative water-saving technologies.
- Exploring what devices or systems are available in Ireland, along with the costs and limitations for their installation or use.
- Addressing differences between technologies which could be retrofit into existing houses and those which would be more suitable for new builds.

(2) Legislation related to water conservation

- Identifying where and how legislative provisions can be strengthened to support and secure water conservation measures in Ireland.
- Exploring how any changes might fit into EU regulations.
- Identifying mechanisms to improve building regulations with regards to domestic water conservation measures.
- Assessing the feasibility of extending the Building Energy Ratings (BER) to include water conservation measures or develop a new compulsory water conservation-related certificate based on the BER model.

(3) Water efficiency labelling

- Investigating relevant labelling schemes for domestic appliance water consumption.
- Identifying international best practice in Water Efficient Labelling, to guide an Irish process if applicable under EU legislation.

(4) Water conservation incentives

- Developing a list of key recommendations for domestic water conservation incentives, which can subsequently be proposed to the Government, based on international best practice.
- Best practice comparisons should be drawn primarily from countries that have similar water policy and management structures to Ireland.

(5) Education and awareness

- Assessing the current public education and awareness programmes in Ireland.
- Identifying gaps and recommending further programmes to address any such gaps.

1. Available technology in domestic water conservation

The terms used to describe water-saving products are wide-ranging. Butler & Memon (2005) define five distinct terms used within water demand management (Table 1). Whilst the language used in the request for tender centred on water conservation and efficiency, technological solutions from all five terms are presented in this Work Package (Figure 5).

Table 1 Definition and description of five water-saving terms (Butler & Memon, 2005).

Term	**Definition**	**Description**
Water Conservation	*Doing less with less*	Particularly appropriate in times of drought. Acceptability is very culturally dependent. e.g. don't water the lawn.
Water Efficiency	*Doing the same (or more) with less*	No lifestyle change is required. Often efficient fittings deliver multiple benefits, such as reduced energy consumption. e.g. tap aerators, low-flow shower-heads
Water Sufficiency	*Enough is enough*	Involves optimisation. Savings depend on correct use. e.g. dual flush toilets.
Water Substitution	*Replace water with something else, such as air*	Involves technical alternatives, e.g. vacuum toilets or compost toilets. Some alternatives to water may have a higher environmental impact.
Water Reuse, Recycling and Harvesting	*A potentially virtuous circle.*	Reuse refers to direct reuse with minimal treatment e.g. rainwater harvesting, or shared baths. Recycling involves a treatment process prior to reuse, e.g. greywater or blackwater recycling.

In the absence of water conservation measures, the traditional approach to meeting increased demand may be to increase supply, but there are financial, geographical and sustainability concerns in doing so. A 2018 EPA report on water stewardship in Ireland noted that a demand management approach was most likely to deliver the "*most value out of the existing water supply*" due to the geographical mismatch between the most abundant supplies and the location of the majority of the population (Stockhill et al., 2018).

Two approaches taken to address water conservation include targeting behavioural change and/or promoting the use of water- saving technology (Beal and Stewart, 2011). This chapter provides a review of national and international literature relating to technologies available for domestic water conservation. The technologies have been categorised by micro-component, end-use and method of implementation, and evaluated in terms of their likely water savings, their technology readiness and other considerations such as cost and ease of integration.

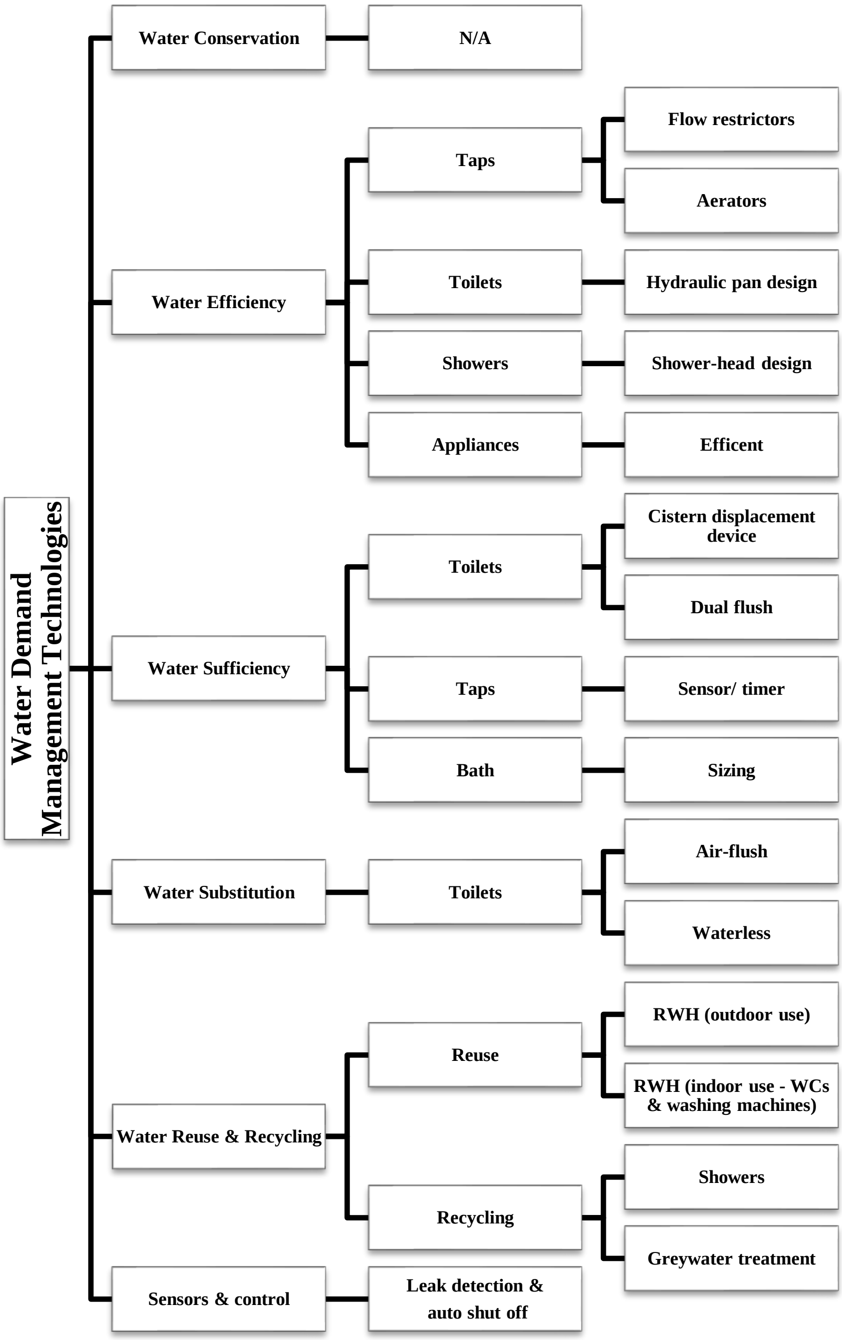


Figure 5 Examples of water-saving technologies for Butler & Memon's (2005) categories.

1.1 Domestic Water Use in Ireland

Domestic water consumption is typically reported as:

- per household consumption (PHC) in litres/property/day or
- per capita consumption (PCC) in litres/person/day.

PCC will be used throughout this report for consistency. Ireland ranks 10th highest out of 25 of 27 EU countries for PCC at 133 litres/person/day, based on a review by Smart Water Magazine where data for Latvia and Lithuania was not available (Smart Water Magazine, 2021). The review included 25 EU countries, along with three non-EU European countries (Norway, Switzerland and the UK) (Smart Water Magazine, 2021) (Figure 6). The majority of countries reviewed were reported to use between 80 – 150 litres/person/day, but there were four countries – Switzerland, Italy, Portugal and France – where reported PCC was in greater than 150 litres/person/day (Smart Water Magazine, 2021). Reported domestic consumption varies as widely as 15-20 litres/person/day in Uganda, to more than 500 litres/person/day in the USA (IWA, 2016). Variation in consumption is influenced by legislation, climate, property type and rate of occupancy and societal and cultural habits amongst others. The method used to measure and estimate household consumption, can also affect the consumption rates recorded. 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 (Lawson et al., 2018).

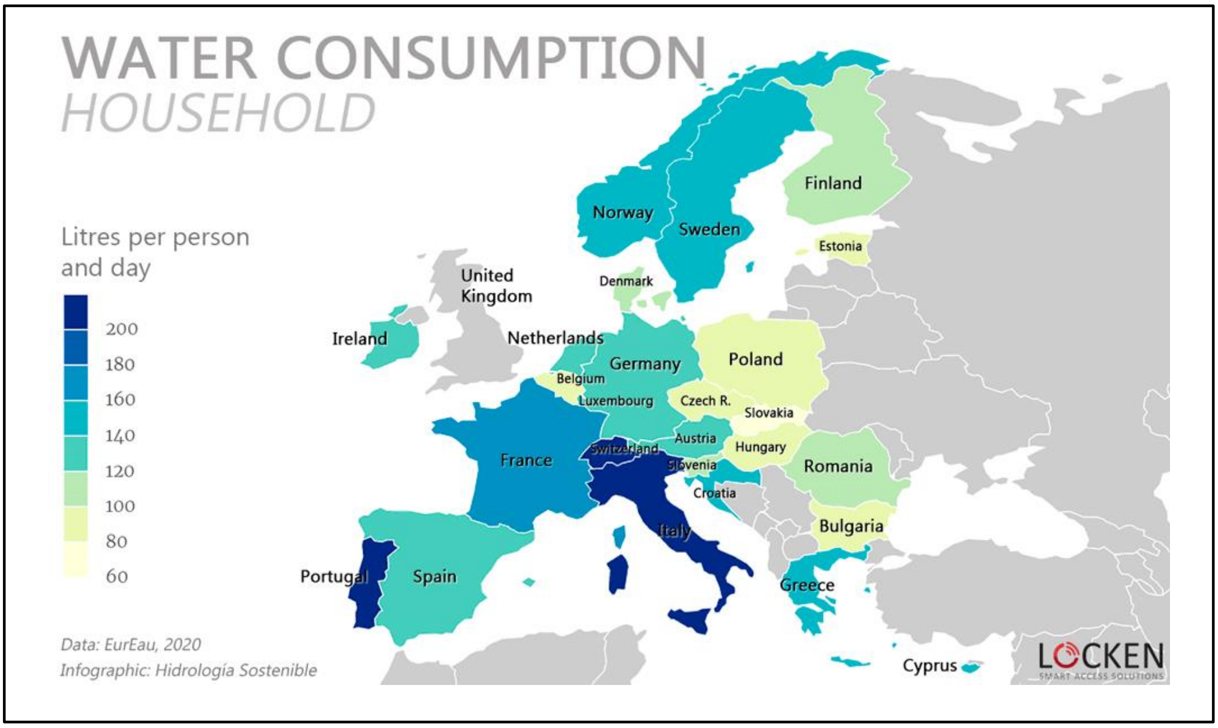


Figure 6 Water consumption in litres/person/day in Europe (Smart Water Magazine, 2021)

Water is primarily used in three main areas of the home: the bathroom, the kitchen and the garden. Figure 7 shows an approximate breakdown of water use in a typical Irish house based on data from Marshallsay, 2018 and Fennell et al., 2018. It does not include occasional water losses due to leaks or plumbing issues (Irish Water, 2018). Actual use per household will vary due to the type of devices (or micro-components) present in the household as well as a range of macro-components, such as the behavioural habits of the occupants, plumbing losses, and the weather (Figure 8). Understanding the variation between households is key to delivering reductions in future household demand (Lawson et al., 2018)

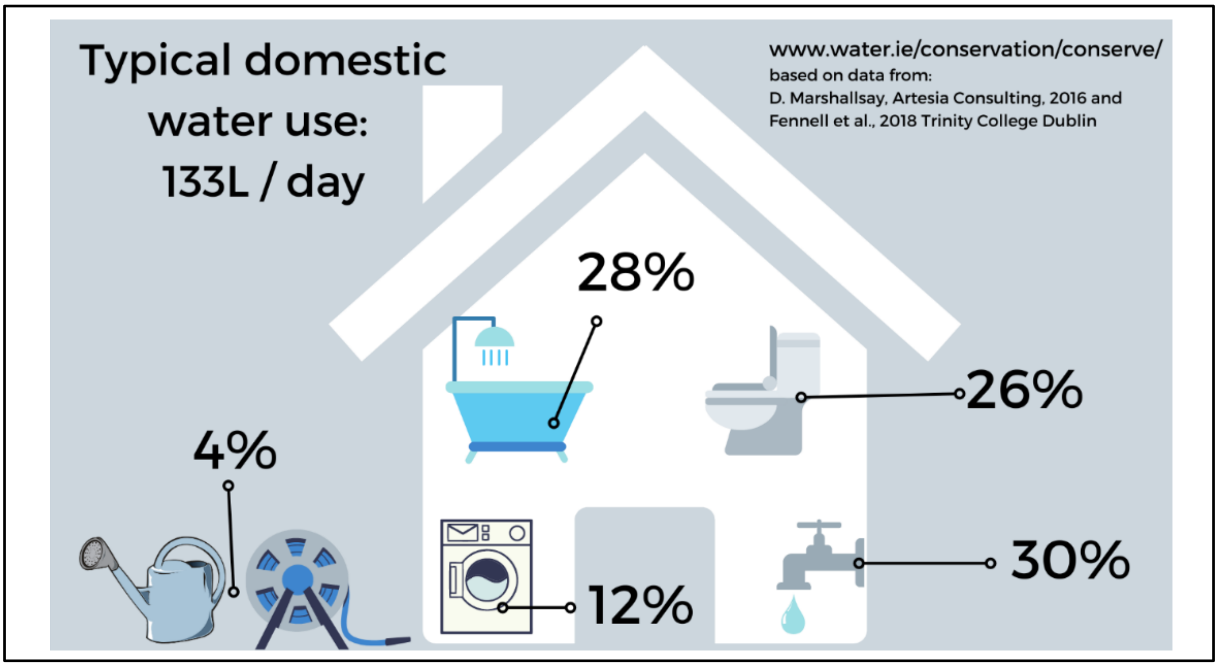


Figure 7 Domestic water use in a typical Irish house. Adapted from (Irish Water, 2018)

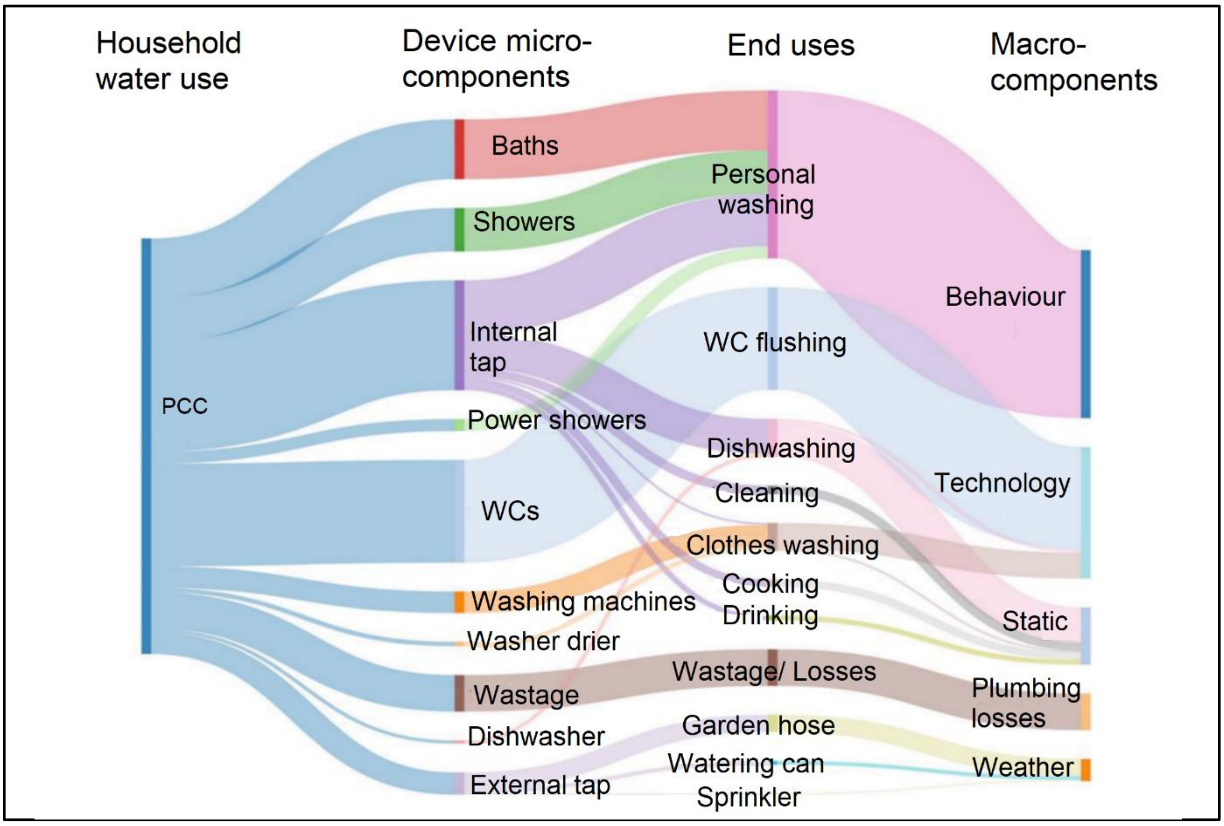


Figure 8 The relationship between household use, micro-components, end use and macro-components, adapted from Lawson et al., 2018

1.2 Micro-components

The use of water-efficient micro-components is a key water demand management strategy, that does not require a change in lifestyle or behaviour (Butler & Memon, 2005).

1.2.1 Taps

Domestic taps are one of the most frequently used water-using micro-components. The amount of water used in a tap is determined by its frequency of use, duration of use and the flow-rate of the tap. Whilst the first two are dependent on user behaviour, the latter is determined by the design of the tap, any additional sensors, controls or fittings installed, and other factors such as water pressure (Fidar *et al.*, 2016). There is wide variation in the types of tap available on the market, in terms of shape, construction and flow rate, as well as the accessories available to restrict the volume of water flow including aerators, flow limiters (eco-buttons), flow regulators and pressure regulators (Figure 9). The type of tap used – whether that is a mechanical single or double handed fitting; an automatic shut-off tap equipped with a push button to release a set volume of water; or electronic taps, where water rate and volume is controlled by a sensor within the spout – will affect the amount of water used per event (Englart and Jedlowski, 2019).

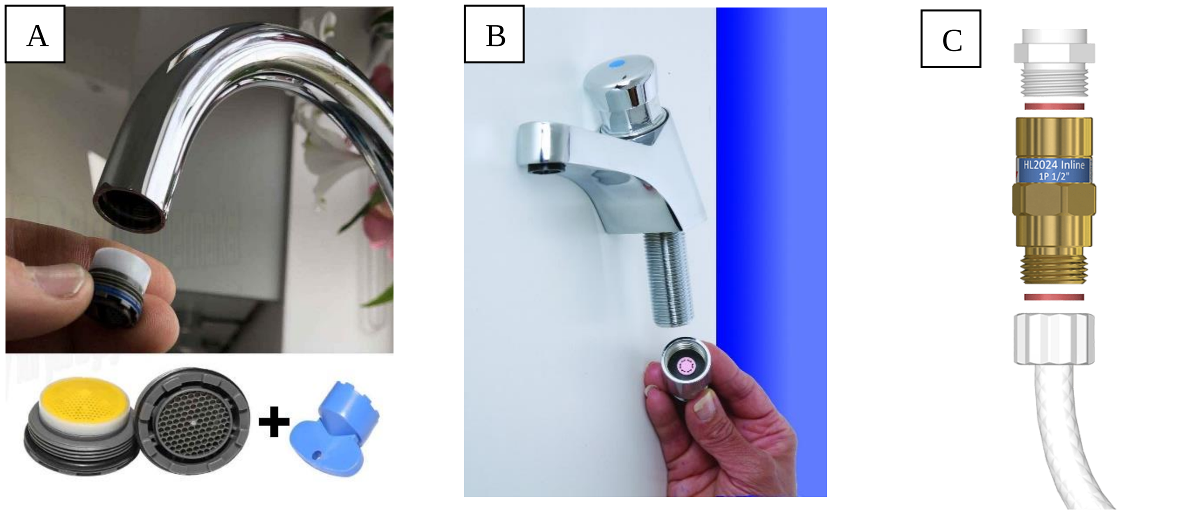


Image source: www.lowenergysupermarket.com

Image source: wwww.freeflush.co.uk

Image source: www.hl2024.com

Figure 9 Water-saving devices for taps including: A) tap aerators that can be inserted into the spout B) tap flow regulators that can be attached when fitting the tap and C) pressure regulators that can be inserted into the pipe.

There are widely varying conclusions about the effectiveness of water-saving taps. Manufacturers claim that installing or retrofitting water-saving taps can reduce water use by 50 – 85% (Fidar et al., 2016). However, in the peer-reviewed literature, Mayer et al., (2000) report a 13% reduction after retrofitting tap aerators; Neve (2006) reported a 50% water-saving from retrofitting push taps; but Hills et al., (2002) concluded that low-flow taps resulted in a greater water consumption per event than conventional taps. Gleick et al., (2003) suggested that user behaviour is the most significant variable in predicting water-use in taps, rather than the type of tap installed. Conventional taps are estimated to have a greater flow rate than electronic taps, but the latter tend to have a longer event duration; a factor which is underpinned by user-behaviour (Fidar et al., 2016).

Taps account for the largest consumption of water in the home in Ireland (), but beyond that, the energy and carbon footprint of water use via taps is the highest among all the micro-components. Therefore, efficient use of water in taps can potentially contribute towards reduction in carbon emissions through a significant reduction in energy demand (Englart and Jedlikowski, 2019), provided the use of technology is supported by measures to influence water users' behaviour.

1.2.2 Showers/baths

Water-used in showers and baths is one of the highest contributors to household demand (). Given that water used in showers is primarily heated, any conservation of shower water will consequently result in an energy and greenhouse gas saving too. Total water consumption in showers is affected by macro-components including local water governance, individual attitudes, household composition and socio-demographic characteristics, as well as micro-components including the type and efficiency rating of the shower head or system installed. Makki et al., 2013 found that household size and composition, as well as the showerhead efficiency rating, are the most significant predictors of shower usage, explaining 90.2% of the variation in household shower end use consumption.

There are a variety of water-efficient shower systems available on the market, ranging from retrofittable low-flow showerheads (Figure 10), to devices that monitor and inform usage in real-time (Figure 11), or can be programmed to personal use patterns (Figure 12). Finally, systems exist that collect and purify shower water after use, recycling up to 90% of the water used (Figure 13). A conventional shower in Ireland will deliver a flow rate of approximately 12 L/min. A water-efficient showerhead (e.g. Figure 8) is likely to reduce this by 25 – 50% to approximately 6 – 9 L/min. However, there is a risk that the impact of engineered savings can be negated by human behaviour. A study by Inman and Jeffrey (2006) revealed an increase in water consumption *after* the installation of water saving devices, arising from an increase in shower duration due to the residents' belief that they were saving water through the installation of efficient technology.

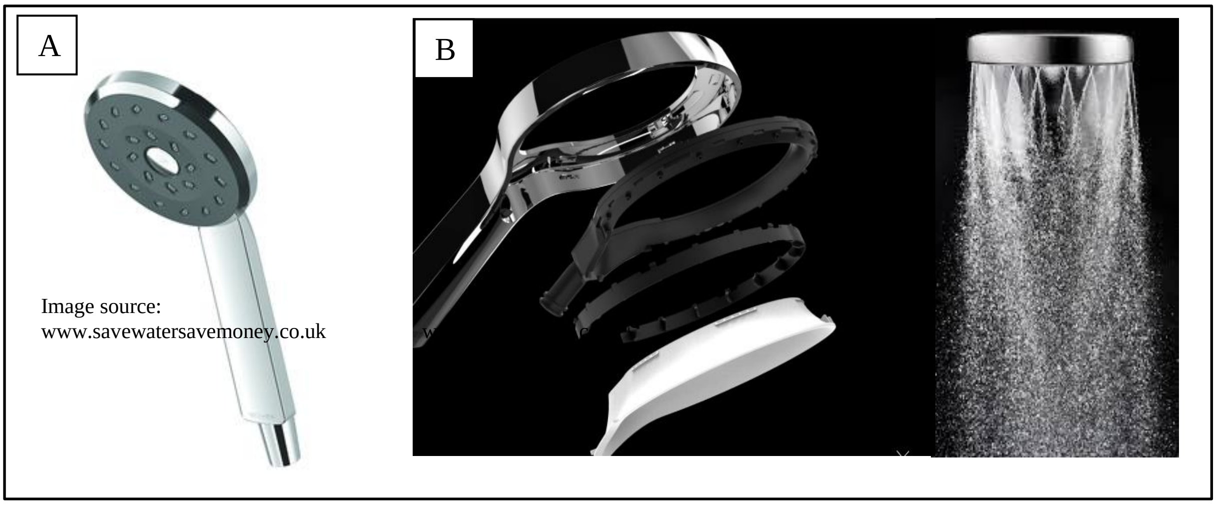


Figure 10 Examples of retrofittable low-flow showerheads

The use of electronic visual and/or alarming monitoring devices within a shower enables immediate feedback to be provided to water users (Willis et al., 2010). This electronic feedback is quicker and more frequent than feedback provided by bills, and is better able to inform and influence consumer behaviour (Willis et al., 2010; Kenney et al., 2008). In a study of 44 households in Australia, Willis et al. (2010) found that average shower duration decreased by 1 minute and 20 seconds (18.6%) and mean volume of water used decreased by 27%, following the installation of an alarming visual display monitor in their showers, despite only a modest change in shower flow rate (from 10 litres/min to 9 litres/min). Electronic upgrades to showers (such as HYDRAO, Figure 11 or Amphiro) can be relatively easy to retrofit to enable users to understand factors such as water temperature, water use and energy consumption in real time.

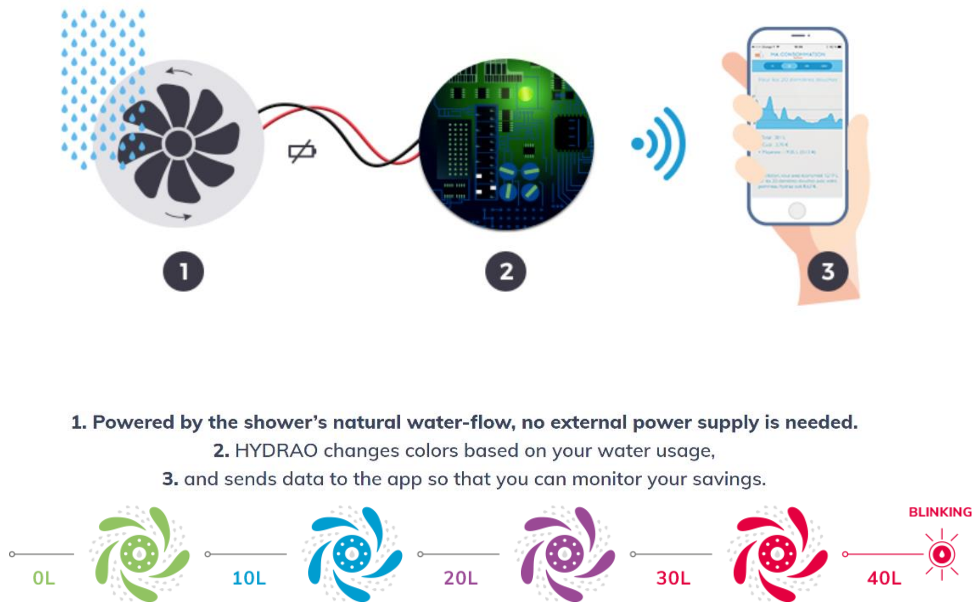
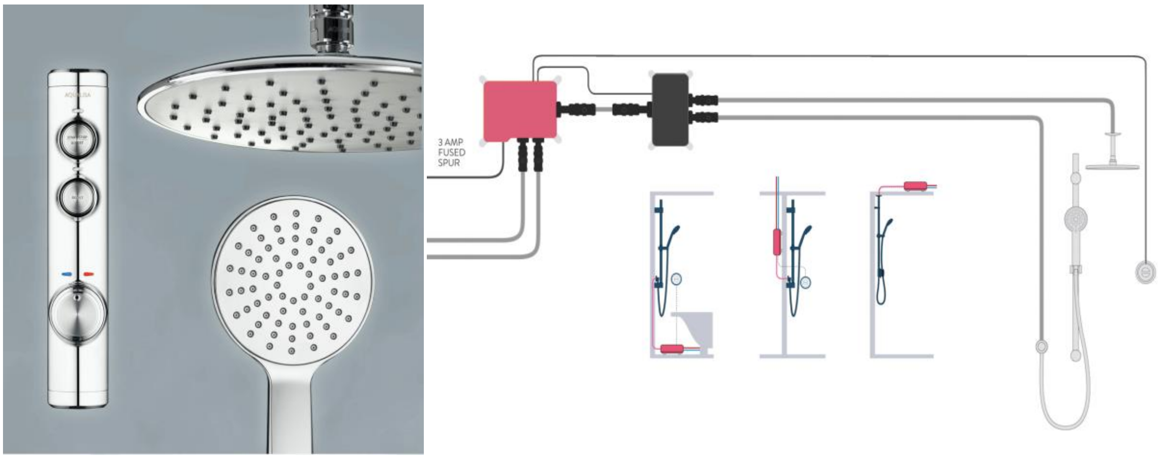


Image source: www.hydrao.co.uk

Figure 11 A showerhead by HYDRAO which is colour-coded from green to red to inform users of their water consumption in real time.

Internet of Things (IoT) technology or connected appliances are commercially available and applicable to a wide range of domestic activities (Crabtree et al., 2019). Personalisation is a key driver of this technology, offering insight and opportunity to tailor appliances to predict and react to consumers' changing needs and circumstances . Smart showers (e.g. Aqualisa Figure 12) include a variety of sensors and controls to monitor flow rate, water consumption, water temperature (Khan 2018). They can include features such as scales that log the weight of personal cleaning products to provide information on product usage (Crabtree et al., 2019). The information gathered by a smart shower could be beneficial for the end-user (.e. in promoting efficient behaviours, or 'learning' the types of showers household members prefer (Khan, 2018; Crabtree et al., 2019). But it could be more broadly applicable in demand-side management, if users could be rewarded or incentivised to behave in a predictable manner, enabling pressure across the network to be more sustainably managed in line with real time demand (Crabtree et al., 2019).



Images source: www.aqualisa.co.uk

Figure 12 A smart shower system which can be programmed to personal use patterns using proximity sensors and timers.

Finally, recycling showers combine smart elements – such as water temperature control and evaluation of water savings – with greywater treatment and reuse. Systems exist on the market (e.g. Figure 13, Orbital Systems) which collect, analyse, treat and recycle water, preventing up to 90% of shower water being discharged as wastewater. These systems include sensors to monitor the quality of the used water up to 20 times per second, to assess whether the water can be efficiently filtered and disinfected using UV-light prior to reuse. Despite a substantial reduction in water use, there is likely to be a trade-off in terms of the energy intensity of the process of delivering point of use water treatment within water recycling (Lee et al., 2017). The cost-benefit of this could be determined through life-cycle analysis.

Images sourced from www.orbital-systems.com

Figure 13 A recycling shower system with built in sensors and greywater treatment.

1.2.3 Toilets

Dual flush toilets were introduced to operate with two separate buttons; one with a small flush for liquid wastes and one for a larger flush for solid wastes. The intention was to reduce water demand by ensuring larger flush volumes are used only when necessary. However, a study in the UK found that approximately 400 million litres of water leaks from UK toilets every day – enough to supply 2.8 million people (Waterwise, 2020) – and the majority of those that are 'leaky' use a dual-flush mechanism. This may be an example of a good proposition, whereby a poor long term design was adopted. A single leaking toilet can waste between 215 - 400 L/day and approximately 5 - 8% of all toilets are leaky (Waterwise, 2020).Cistern displacement devices (Figure 14) are frequently used in domestic toilets to offset water use in a conventional toilet (7.5 litre or more capacity). The device is essentially a bag filled with crystals which expands within the cistern to save 1.2 litres of water on every flush.

Image source:
www.nwl.watersavingkit.com

Figure 14 'Save a flush' toilet displacement device

Ultra-low flush toilets (such as The Propelair®, Figure Figure 15) use only enough water to rinse the pan and refill the water trap within the U-bend (Melville-Shreeve et al., 2021). The toilet is flushed through the high-pressure release of air, which (with the lid sealed) forces the contents through the U-bend and into the downstream sewer pipework. It has a two-section cistern, one for air and one for water. Before flushing, the lid is closed to form a seal and when the flush sensor is activated 1.5 litres of water enters the pan to wash it, followed by air from a unique patented pump. The seal created by the lid forces a powerful, reliable flush which causes the entire contents of the pan to empty. Water consumption is reduced by up to 75% compared to a 6-L cistern (Melville-Shreeve et al., 2021).

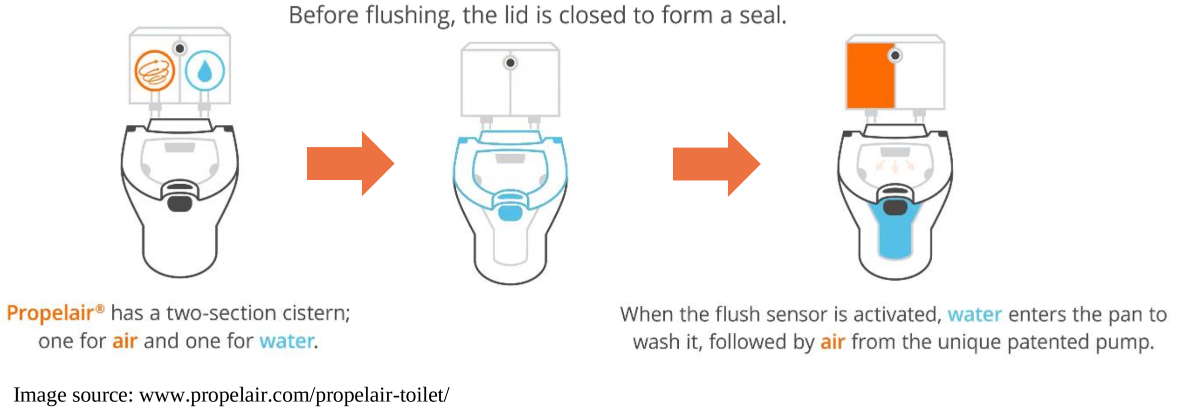


Image source: www.propelair.com/propelair-toilet/

Figure 15 The Propelair® ultra-low flush toilet which uses an air flush mechanism.

Waterless toilets exist in a variety of forms (Figure 16), but are primarily based on composting principles i.e. the aerobic and anaerobic breakdown of solid waste, eliminating the consumption of potable water consumption and the discharge of wastewater (Olanrewaju, 2015). Waterless toilets have been implemented in domestic and non-domestic settings (Olanrewaju, 2015). Examples of commercially available composting toilets include: Separett, Kazuba cabins, and Loowatt amongst others. Separett is a waterless compost toilet which separates solid waste from liquid, using a fan to quickly dry solid wastes and reduce odours (Separett, n.d.). Urine is diverted (via gravity) to a small soakaway or container outside of the toilet via the front part of the toilet bowl. The fan used within this toilet requires around 2.5 watts of power at 12 volts DC, which could be powered by a solar panel or battery (Separett, n.d.). The toilet itself is made from polypropylene, creating a similar appearance to a conventional domestic toilet. Cabin-based composting toilets are more suited to outdoor, rural or larger scale applications including allotments, community gardens, camping sites, schools etc (Waterless toilets, n.d.). Loowatt toilets have a patented flush (which may be manual or electric) which seals waste into a container (Loowattt, n.d.)

Image source: www.waterlesstoilets.co.uk | Image source: www.waterlesstoilets.co.uk | Image source: www.loowatt.com

Figure 16 Examples of water less compositing toilets.

The Nano-Membrane Toilet (Figure 17), a waterless toilet developed by Cranfield University (Hennigs et al., 2019; Mercer et al., 2019), is designed for single-household use (up to 10 people) and can process a mixture of urine and faeces. The flush uses a unique rotating mechanism without water. Solids separation is achieved through sedimentation and water is separated (primarily from urine) using hollow-fibre membranes. The nano-membrane wall facilitates water to be transported as vapour, rather than liquid, improving the high rejection rate of pathogens and odorous compounds. Water can be collected for non-potable reuse in washing or irrigation applications. The resulting solids are transported by mechanical screw to a combustor to generate energy which powers the membrane processes.

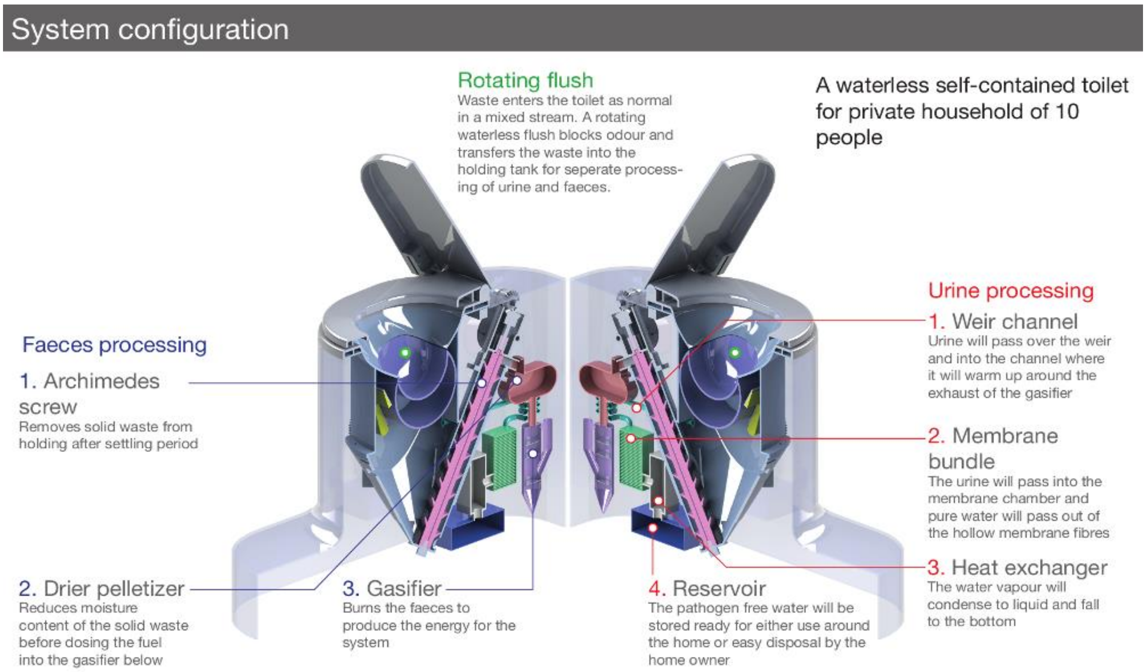


Image source: www.nanomembranetoilet.org/

Figure 17 Configuration of the waterless nano-membrane toilet developed at Cranfield University.

1.2.4. Appliances

White goods are major sources of domestic water consumption () accounting for 10 – 15% of the average household's water use. Water efficient white goods can achieve major water savings. A conventional washing machine will typically use up to 80 litres per wash, whereas a water efficient appliance can reduce this by 40-50% to approx. 40 – 50 litres per wash (McCarton, 2003). Technologies are coming to market which can reduce water use further still. The "near-waterless" commercial washing machines (Figure 18) from Xeros Technology Group use a product called XOrb™ to reduce water use by 80% and energy use by 50% (Xeros Technology, n.d.). Water is sprayed into the drum, rather than poured, and XOrbs subsequently "absorb stains and provide a gentle mechanical wash action" to reduce the amount of water and the temperature required to wash clothing. This appliance has primarily been adopted in the commercial market, but could be possible in domestic households in the near future.

Image source: www.xerostech.com/

Figure 18 Near-waterless washing machine.

A typical dishwasher uses between 9 – 12 litres per wash. By comparison, a tap in a kitchen sink will typically have a flow rate of 3 – 6 litres per minute. A water-efficient dishwater may use less than half the water required to wash the same dishes by hand. Manufacturers continue to innovate further; the possibility of a waterless dishwasher becoming widespread in domestic households is not unrealistic in the next 25 years (Lawson et al., 2018b). Figure 19 shows examples of such innovations, including Air-Well, (designed by Denes Janoch), which uses atmospheric water to collect and produce water, and generates energy from the organic waste collected during the dishwashing process (Figure 19A) (Mecc Interiors, 2020); The Waterless Cleaner (designed by Beata Patašiūtė), which uses electromagnetic microwaves to remove food residue from dishes (Figure 19B) (Mecc Interiors, 2020); and Granuldisk (a commercial dishwater manufacturer led by CEO, Peter Schön,) which uses small plastic granules to wash pots, pans, and other kitchen utensils, whereby the granules last for 2,500 cycles (Figure 19C) (Mecc Interiors, 2020).

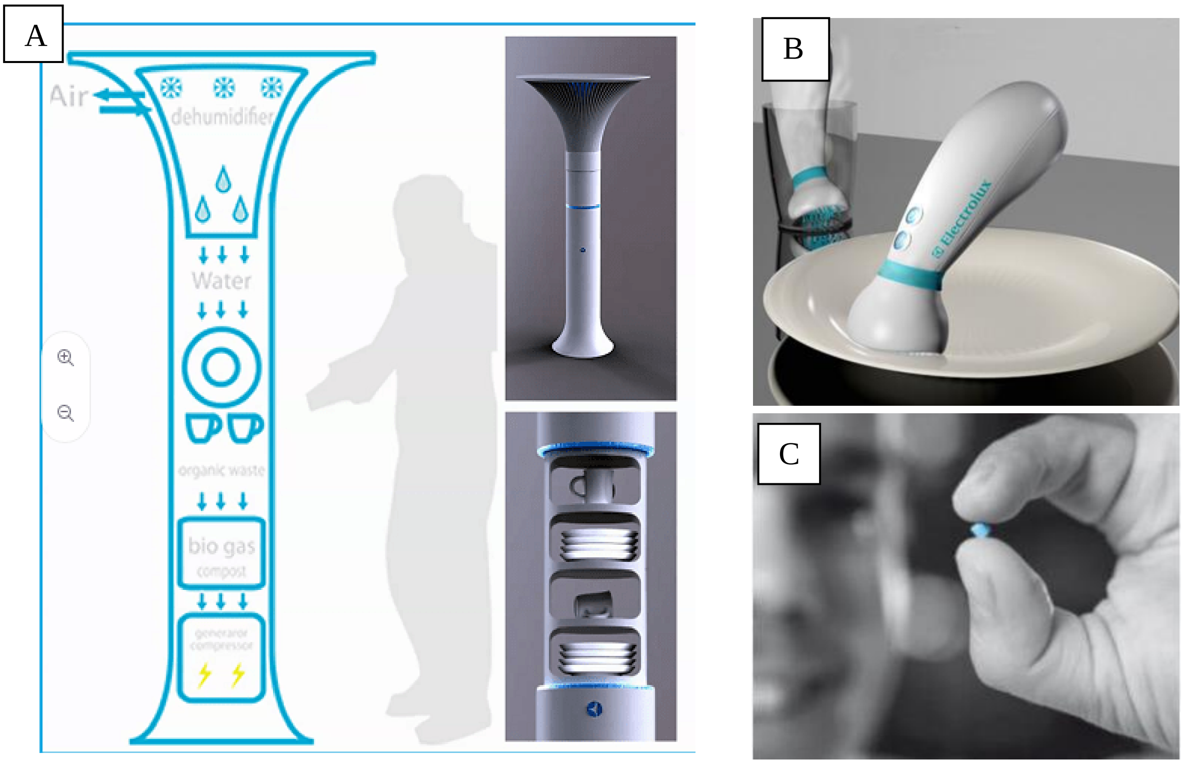


Image source: www.meccinteriors.com/designbites/is-a-waterless-dishwasher-in-our-futures

Figure 19 Water-less dishwater cancepts including Air-Well (A), The Waterless Cleaner (B) and Granuldisk (C).

1.2.5 Outdoor use and greywater recycling

Rainwater reuse is frequently found in locations with high water demand for "non-potable" water e.g. irrigation for allotments and gardens. Outdoor water demand is highly seasonal, and potential yield of rainwater harvested is a function of roof size, roof type, filter efficiency and annual rainfall (McCarton and O'Hogain, 2003). This yield can range between 25 m^3 and 945 m^3 for plan roof areas between 50 – 1000 m^2, across the annual rainfall of 750 – 1400 mm typically seen in Ireland (Met Éireann, n.d; McCarton and O'Hogain, 2003). Water butts can run dry in summer spells, and larger rainwater harvesting systems are needed to provide reliable supplies for longer dry spells associated with a changing climate. The benefit from operating a pumped rainwater supply can be realised throughout the year when rainwater harvesting is used in non-potable applications within the home. Typically rainwater can be used with low levels of treatment in WCs. Cartridge filters and UV treatment may be necessary where rainwater is used in laundry applications. Successful schemes (e.g. Bicester) were deployed at scale in the UK following introduction of the Code for Sustainable Homes (Department for Communities and Local Government, 2010) (e.g. section 2.4). However, this was withdrawn in 2015 and the rate of domestic RWH uptake has fallen accordingly.

In the absence of the Code for Sustainable Homes, the uptake of rainwater and greywater recycling systems tends to occur in developments where there is a planning and building regulation specification to stay below a given level of per capita consumption. One such example is a greywater recycling system installed by SDS Limited at a 25-residence development in Kensington, London (Envirotec, 2021) (Figure 20), where mains water demand was required to stay below 110 litres/person/day. Through the reuse of water, overall mains demand was calculated to fall around 15% below that at approx. 90 litres per person per day (Envirotec, 2021). The system (Figure 20) enables the water used in baths and showers to be collected, treated and reused for toilet flushing throughout the building.

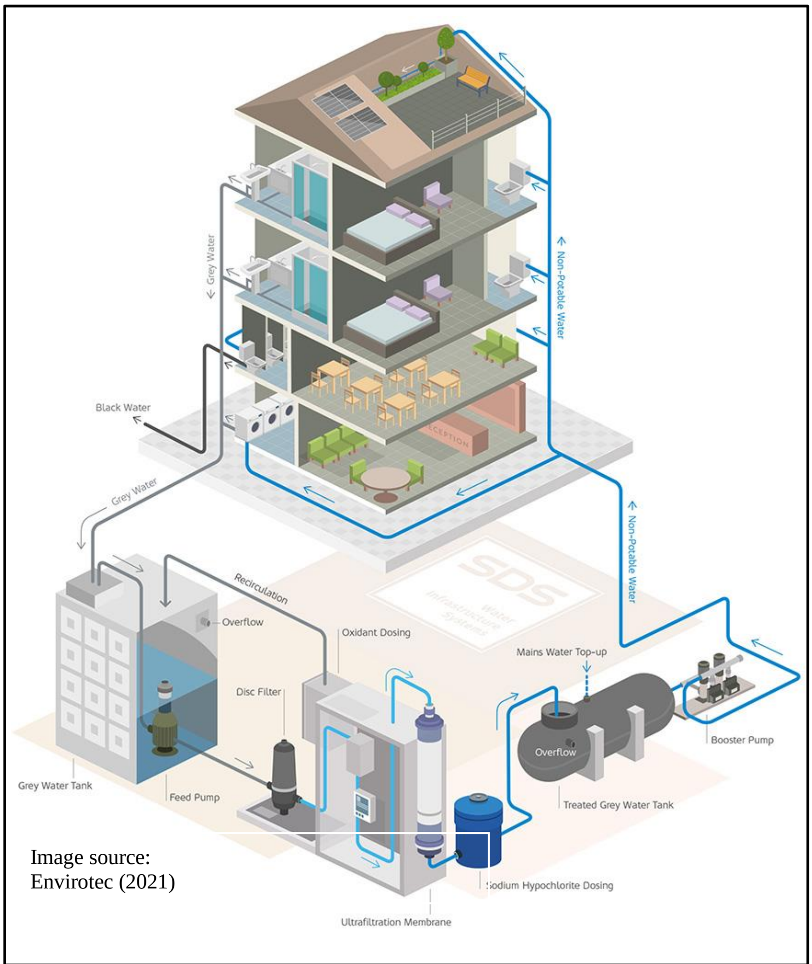
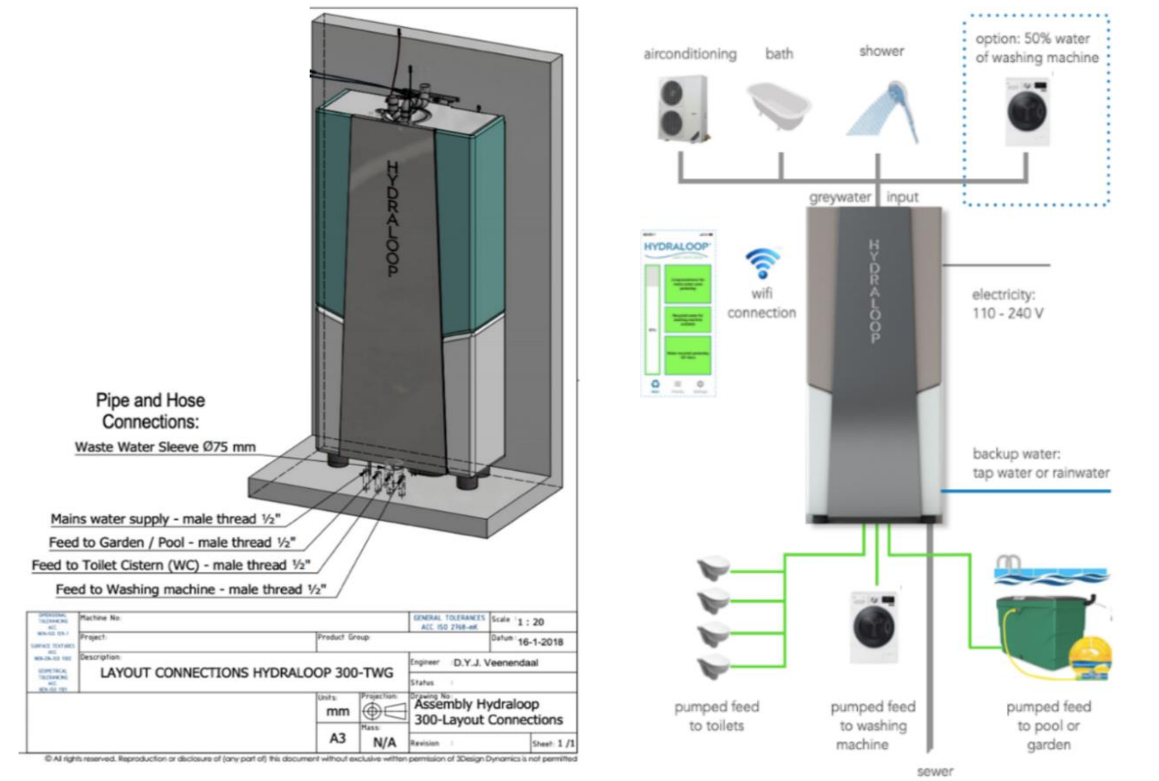


Image source: Envirotec (2021)

Figure 20 SDS Greywater on Demand system

The “Greywater on Demand” system also has a small footprint, and is able to fit in the building’s plant room more easily than a conventional membrane bioreactor (MBR) (Envirotec, 2021). Used water is collected from 27 outlets around the building, transferred via a network of pipes to a holding tank in the basement plant room, before being pumped through a disk pre-filter system and dosed with a small amount of chlorine. After this, it enters the hollow-fibre ultrafiltration membrane system, which has an automated integral backwash resulting in a very high level of water quality (SDS, n.d.). The treated water is then stored in a separate tank and pumped, as needed, to flush 88 WCs throughout the development (Envirotec, 2021). The UK market includes case studies of similar systems produced by other providers including Aquality, Graf and Stormsaver.

Hydraloop (Figure 21) is another greywater recycling system designed for domestic, commercial and hotel buildings. It is fed from the wastewater of a bath and/or shower, and the water can be reused for toilet flushing, washing machine use, or garden irrigation. It is fully automated, self-cleaning and low maintenance (without any filters, membraes or chemicals) and has BREEAM and LEED certification. Whilst these examples provide good technological solutions, schemes like this can be "turned off" without appropriate regulation and therefore may not be fully effective as a stand-alone solution. Similar systems have been used to good effect in European settings for example Berlin (Nolde, 2013), where regulations permit energy recovery from warm greywater as well as water reuse in residential tower blocks.



Images sourced from www.hydraloop.com

Figure 21 Schematics of a Hydraloop greywater recycling system.

1.4 Method of Implementation

The technologies presented in section 1.2 – 1.3 vary in terms of the technology readiness, cost and ease of installation. Three scenarios are presented below: retrofit, replace and re-imagine.

1.4.1 Retrofit solutions

Retrofit solutions are affordable and easy-to-implement devices that can be installed by the householder themselves to start saving water within the home. These solutions consist of the highest technology readiness level (TRL) options, many of which are also very low cost, and simple to install (Figure 22)

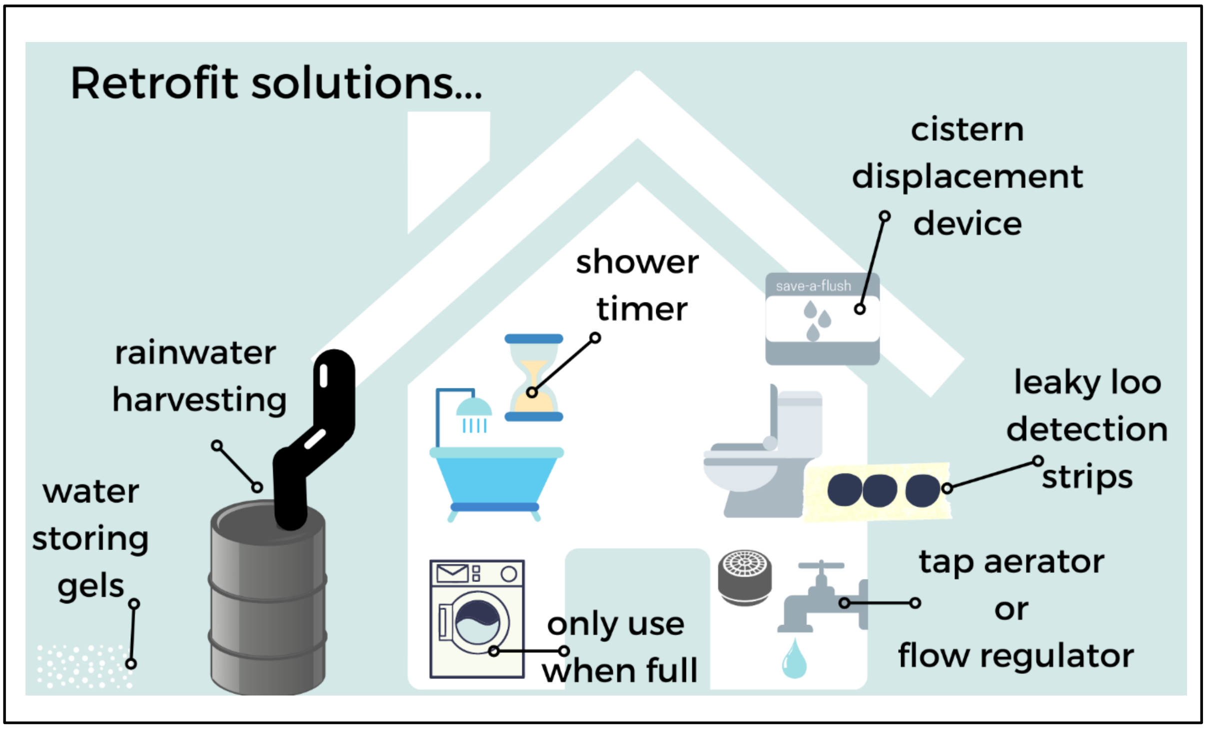


Figure 22 Retrofit solutions to reduce water demand in a typical Irish home.

Irish Water lists the following water saving devices on their website (Irish Water, 2019b):

- toilet cistern bag,
- dual flush,
- shower timer,
- aerated tap/showerhead, and
- water butt

stating "*these water saving devices are available from DIY stores or garden centres. You can contact a plumber for advice on what water saving devices are suitable for your home or business*". However, the cost of purchasing these five items would be in the region of €250 if they were to be sourced at a cost to the homeowner from DIY stores in Ireland (Table 1).

Table 2 Typical cost of water savings devices, sourced from suppliers in Ireland (prices obtained in September 2021).

Device	Price (€)	Source
Toilet cistern bag	4.99	https://www.hardwareireland.ie/product/toilet-tummy-cistern-water-replacement-bag/
Dual flush toilet (4 / 6 L)	151.95	https://www.screwfix.ie/p/ideal-standard-della-close-coupled-rimless-toilet-dual-flush-4-6ltr/511jy
Shower timer	9.99	https://renergise.ie/shop/shower-accessories/shower-timer/shower-timer-2/
Tap aerator	9.95	https://renergise.ie/product-category/tap-aerators/
Low-flow showerhead	35.00	https://renergise.ie/product-category/shower-heads/
Water butt	39.99	https://www.woodies.ie/100-litre-water-butt-set-1081507

With the exception of the dual flush WC, many of these devices are provided in free 'water saving kits' supplied by water utilities internationally. Singapore's Public Utility Board (PUB) provide free water saving kits which can help homeowners to save up to 5% of their monthly water consumption (PUB, 2021). Furthermore, in a review of 22 UK water suppliers' water efficiency programmes, 95% were reported to "distribute free of charge home water efficiency devices" (Waterwise, 2015). For example, Figure 23 shows the items that can be obtained from Northumbrian Water. Whilst these items are provided free of charge to the customer, the total cost of these items is likely to be less than €30 to the utility. Some utilities also provide a low-flow shower head, and/or offer discounted rates on water butts too, with the total water saving kit delivered for less than the water conservation grant implemented in Ireland in 2015 (based on prices at www.savewatersavemoney.co.uk in September 2021).

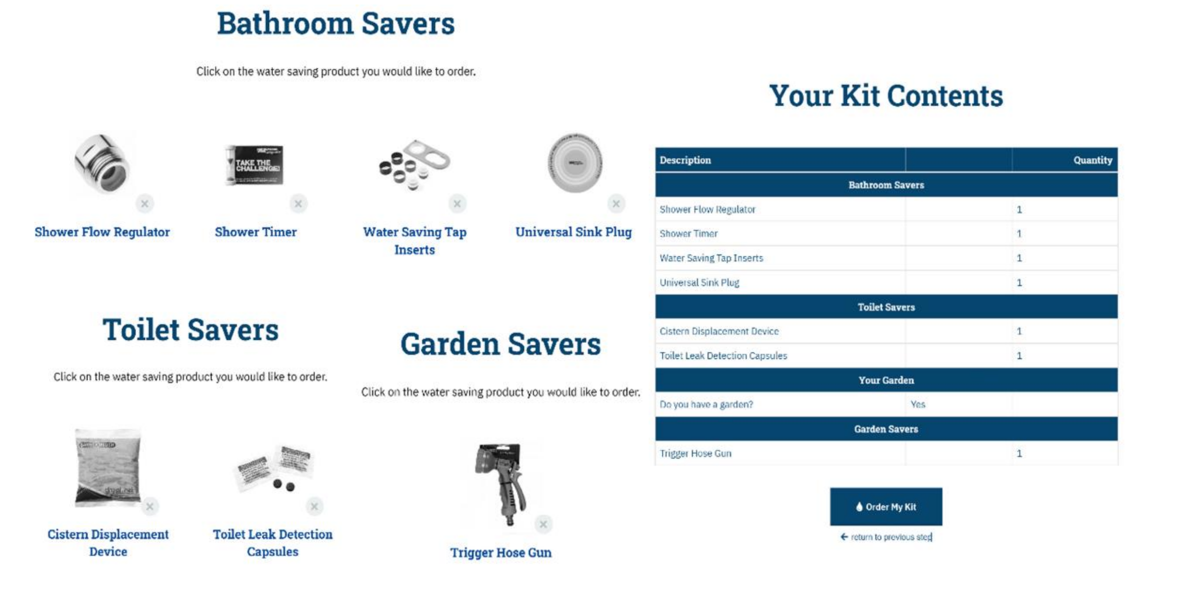


Image source: www.nwl.watersavingkit.com/your-free-water-saving-kit/

Figure 23 An example of the items provided in a free water saving kit by a UK water utility.

1.4.2 Replace existing fittings and appliances

Beyond retrofitting aerators or installing inserts, existing fittings and appliances could be replaced or upgraded with more efficient alternatives (Figure 22). Some of this might be achievable directly by the homeowner (e.g. the exchange of a washing machine or showerhead) but more significant upgrades could require input from a plumber or electrician. For example, in the case of the re-use of harvesting rainwater for WC flushing or washing machine use (Figure 21) or the installation of a new low-flush toilet (Figure 15).

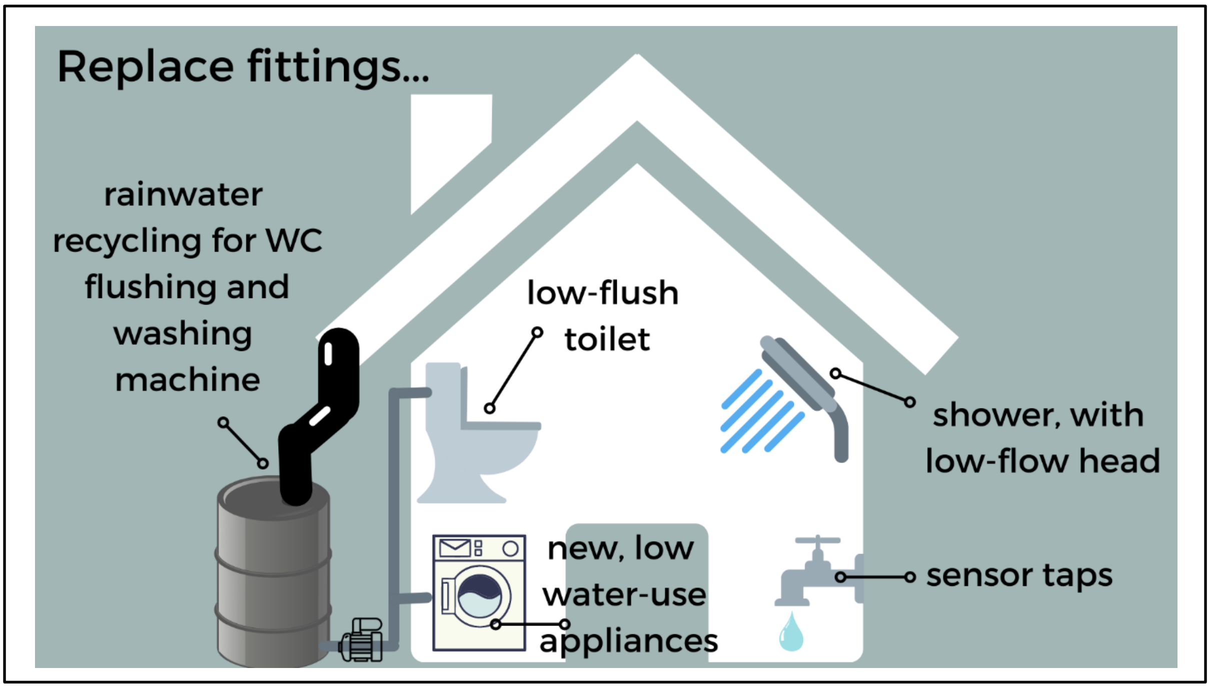


Figure 24 Water-using devices that could be replaced within a typical Irish home to reduce water demand.

1.4.3. Reimagine the entire system

Finally, the third scenario considers a complete re-imagining of water-use within the home around the concept of water neutrality (Figure 25). Water neutrality seeks to ensure that for any new developments, the total water use after development is equal to or less than the total water use in the region was prior to the new development. It is an approach which seeks to manage demand for water in the face of challenges such as an accelerated rate of housing growth, and/or constraints on the availability of water (Environment Agency, 2009).

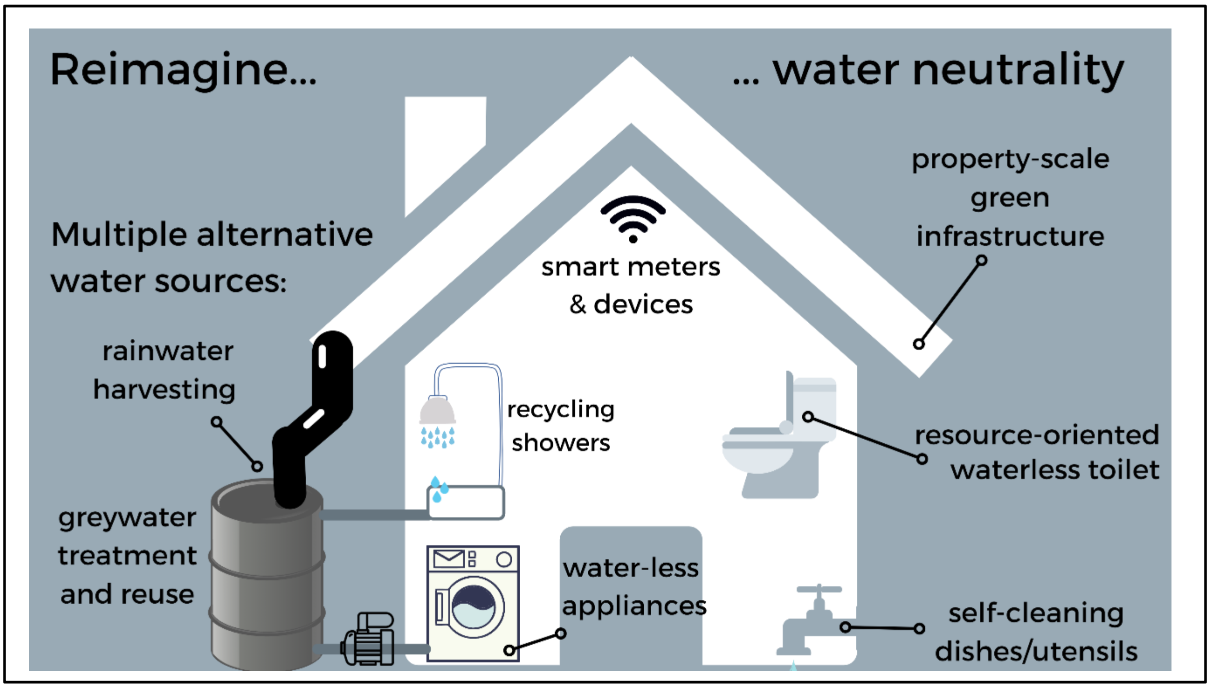


Figure 25 Water use in a house of the future.

There are three steps to achieving water neutrality, also known as "net- zero water buildings" (U.S. Department of Energy, n.d.)(Figure 26). The first involves reducing water use by making the building as water efficient as possible. The second involves installing systems to enable alternative water use, such as rainwater harvesting or grey water recycling. Finally, the third principle involves offsetting any remaining demand in the existing local region (Earl, 2021). Alternative water use is the amount of water consumed from sustainable water sources (not derived from freshwater sources). This includes harvested rainwater, stormwater, recycled greywater, air-cooling condensate and reclaimed wastewater (U.S. Department of Energy, n.d). In a net-zero building, total annual water use should be either partly or totally offset by alternative water use.

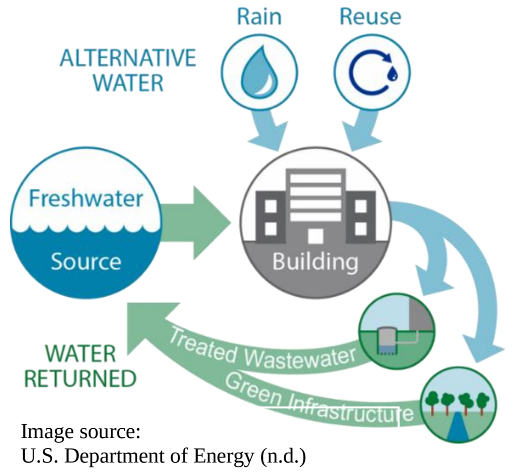


Image source:
U.S. Department of Energy (n.d.)

Figure 26 Net Zero Water Building Concept

Achieving complete water neutrality may not be achievable in all new and/or existing developments. Drivers, such as environmental factors, political or social will, and cost-effectiveness, and constraints, such as the size of the development, and existing / predicted consumption rates, will define the level of neutrality that can be realistically achieved (Environment Agency, 2009). An ideal net-zero water building would use on site alternative water sources to supply the building's water needs and all wastewater would be treated on site and returned to the original water source (Figure 27) (U.S. Department of Energy, n.d.). A 'reimagined' net-zero water building may require the installation of technologies such as waterless appliances (Figure 16, Figure 18, Figure 19), greywater recycling systems (Figure 20, Figure 21), and smart meters. However, it is also likely to involve substantial behaviour change, and regulatory or policy drivers to incentivise uptake.

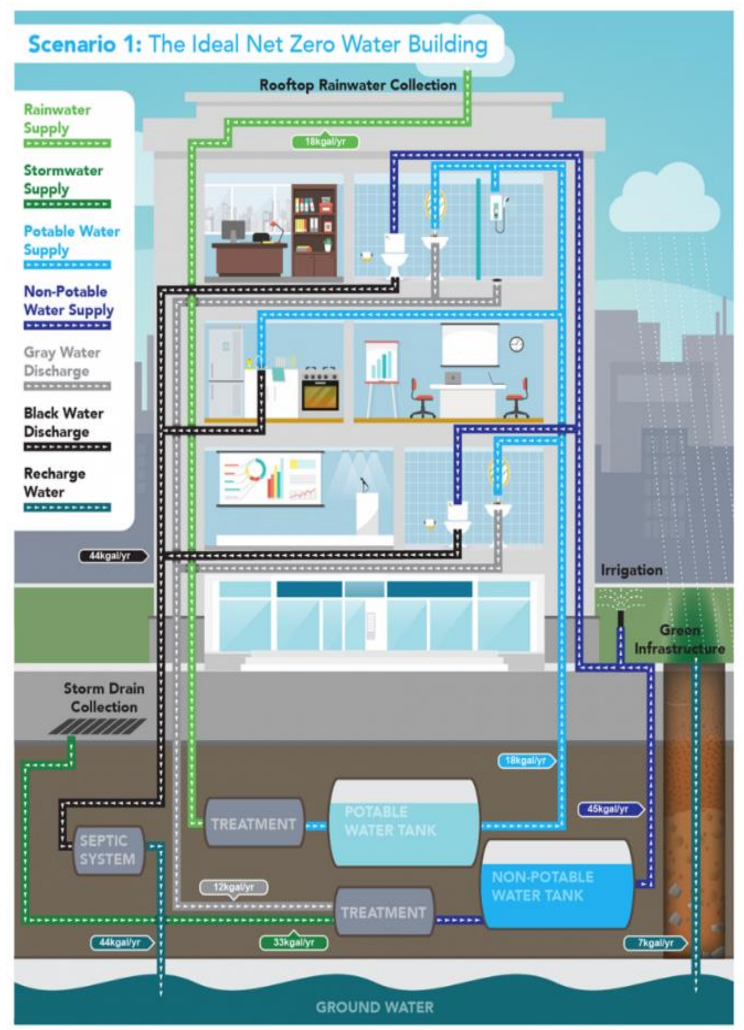


Figure 27 Ideal Net Zero Water Buildings (U.S. Department of Energy, n.d.)

In their 2018 report, Artesia consulting predict how water use inside and outside the home might evolve in the next 50 years (Lawson et al., 2018a). Lawson et al., project that recycling showers (Figure 13); leak free, ultra-low flush WCs (Figure 15); and internet of things (IoT) technology (for home leak detection and warning) will be adopted sooner than smart toilets, waterless appliances (Figure 18, Figure 19) and in-house recycling of water from condensation and other sources (Lawson et al., 2018b). The growth in IoT and smart devices may provide greater flexibility in water use, such that the amount of water conservation required is minimised if water use can be used outside of peak hours.

1.5 Discussion of Potential Water Savings

The amount of water savings achieved will depend on the type and frequency of water-saving micro-components used within the home, and the patterns of user behaviour alongside this. Whilst it is easy to characterise the reduction in the rate at which water is supplied with or without the use of an efficient fitting, the exact impact (i.e. the volume of water saved) is less easy to determine. Studies have shown that the factor of difference between minimum and maximum consumers of water is more significant than the corresponding difference for other utilities such as gas or electricity (Gill et al., 2011). The need to include the effect of behavioural change and awareness of water conservation on the volume of water use / saved complicates any calculation that could be undertaken. A series of scenarios could be provided, demonstrating which solutions offer the largest potential reduction in demand, but there would be a large amount of uncertainty on any values provided.

If user behaviour is unchanged, the introduction of water-saving devices should lead to a reduction in total water use. For example, water demand from WC flushing will decrease as older larger toilet cisterns become replaced with smaller flush volumes; WCs begin to use non-potable sources (rainwater/greywater) for flushing; and ultimately WCs become waterless. These changes could result in a water saving of between 40 – 90 litres per property a day (Lawson et al., 2018b). Predictions suggest that the frequency of bath use is likely to slowly decline, alongside a reduction in the size or volume of baths too, saving up to 30 litres per property per day. Although showers are likely to prevail, they are likely to become shorter; facilitated by timers, smart devices, education strategies and controls. Low-flow showerheads are likely to generate initial savings, and may subsequently be replaced by recycling systems which are capable of saving up to 65 litres per property a day (Lawson et al., 2018b) if any potential negative impacts on energy use can be addressed. Furthermore, the installation of smart taps and/or boiling or chilled water taps could significantly reduce the amount of water waste, saving up to 20 litres per property per day (Lawson et al., 2018b).

Individually, many of the 'retrofit' solutions will not deliver a huge impact. However, they are cost-effective, readily available, and easy to install, and may have considerable impact if used concurrently (Figure 28). By contrast, technologies falling within the 'replace' or 'reimagine' scenarios are likely to have a larger individual impact, but may not be commercially available at the right price for the domestic market for some years yet (Figure 28). In all cases, a combination of technologies, rather than any one technology in isolation, is likely to deliver the greatest impact in terms of water saving in litres per property per day.

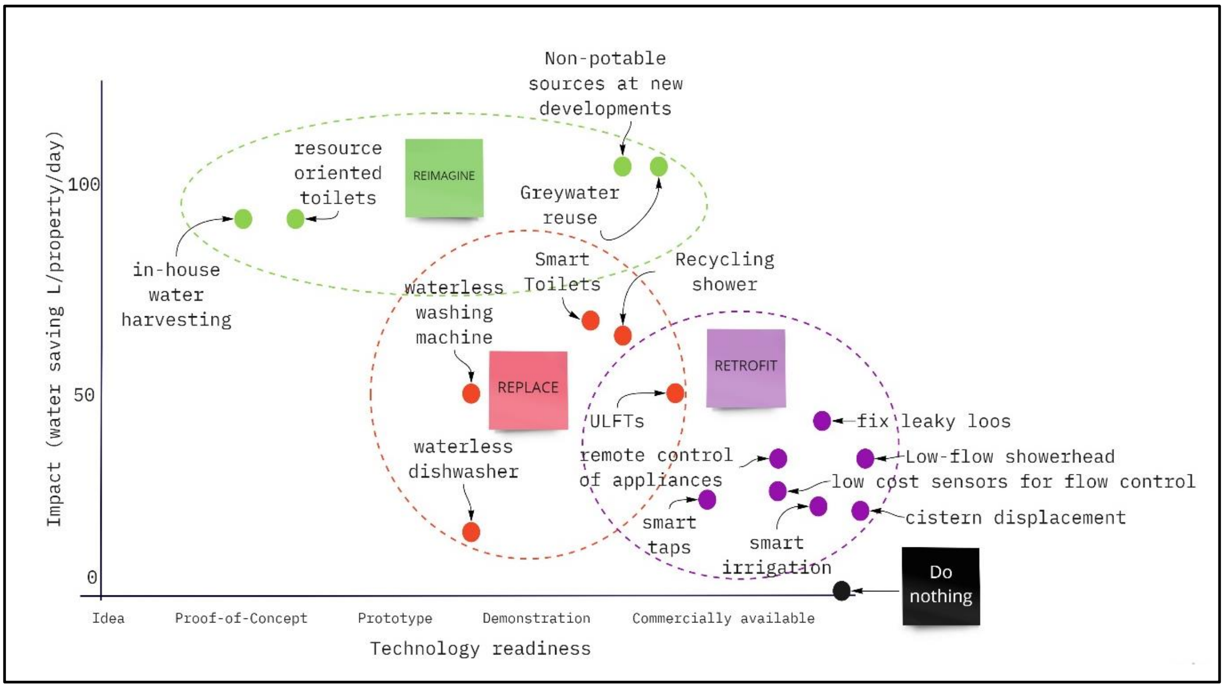


Figure 28 Technology readiness and potential impact of some water-saving technologies.

1.6 Barriers to implementation in Ireland

Despite an abundance of technologies and solutions available in support of water conservation, barrier still remain to their implementation. Firstly, there is a cost associated with purchasing, installing, operating and maintaining such technologies. Without economic incentives to conserve water, it can be hard to justify the costs associated with implementing efficient devices. Secondly, whilst many of the technologies presented in section one have a high technology readiness level, some require further development before they are widely commercially available. Even in such instances where products are commercially available, there may be regional and/or national differences in market availability of such technologies based on the demand for them by consumers. This barrier could potentially be addressed through policy and regulatory mechanisms. Finally, customer preference in relation to bathing and personal care is generally assumed to be for higher consuming/performing products. Therefore, there are challenges to address in terms of customer satisfaction and acceptance of lower-flow technologies. Unless there are policy and regulatory drivers, economic incentives and effective awareness campaigns, the uptake of technologies may be limited. It is also noted that uptake of technology does not guarantee continued maintenance or operation when management and maintenance arrangements are not incorporated.

2. Legislation related to water conservation

2.1 Agencies responsible for water

There are multiple agencies responsible for supplying water to the domestic households in Ireland. The majority (82%) of the population receives their drinking water supplies from Irish Water, with 12% receiving their drinking water from private wells or small private supplies; and 6% receiving drinking water from group water schemes (Government of Ireland, 2020a). Irish Water was created in 2013. They currently manage 539 water supplies, producing over 1.7 billion litres of drinking water every day in treatment plants across the country to serve approximately 4.2 million people (Irish Water, 2021).

Irish Water is regulated by:

- the economic regulator – the commission for regulation of utilities (CRU) – charged with protecting the interests of the customer, and approving appropriate funding to enable the delivery of required services in an efficient manner, and
- the environmental regulator – the Environmental Protection Agency (EPA) – responsible for setting standards and enforcing compliance with EU and national legislation for drinking water supply and wastewater discharge to water bodies.

The National Federation of Group Water Schemes (NFGWS) was formed in 1997 (McCarton and O'Hogain, 2004). Early attempts (i.e. circa 1959) to establish 'group water schemes' were restricted by a lack of financial resources (McCarton and O'Hogain, 2004). However, by the late 1960s, increasing numbers of group water schemes evolved under the grant system for the provision of water in individual houses. By the mid-1990s, the sector accounted for water provision to 29 % of all rural households. In December 1996, the Environment Minister announced the abolition of water charges for domestic water supplies on public schemes (McCarton and O'Hogain, 2004). Group water schemes began to determine how the sector should respond and in 1997 the NFGWS was established. The NFGWS' mission now is to build "*a sustainable and resilient rural water sector that … meets its obligations towards protection of sources, water conservation and the consistent delivery of safe and wholesome drinking water supplies*" (NFWGS, 2018).

2.2 Review of current legislation and policy

In 2000, the Water Framework Directive (WFD) was adopted, "*establishing a framework for the Community action in the* field of water policy" (Directive 2000/60/EC) (Figure 29). Principally, it is a single system of water management based on river basins, rather than administrative or political boundaries, enabling cooperation and joint objective-setting across Member State borders (European Comission, n.d.). After the Directive came into force, Member States had to define their river basin districts geographically, and identify the authorities responsible for water management by 2003. The next task was to undertake a joint economic and environmental analysis. By 2009, Member States had to draw up a river basin management plan (RBMP) creating a programmes of measures to meet the WFD's objectives. RBMPs are updated every six years. The Directive seeks to protect the ecological and chemical status of surface waters, as well as the quantity and chemical status of groundwaters (European Commission, n.d.).

Along with protecting and preserving water quality, the WFD also reflects the need to conserve adequate supplies of water: a resource for which demand is continuously increasing (European Commission, n.d.). To address this, Article 9 of the WFD sought to implement pricing policies

(European Commission, 2012). It states that cost-recovery for water services should be based on the polluter pays principle (European Commission, 2012) and that Member States should enact pricing policies by 2010 to incentivise "*users to use water resources efficiently, and thereby contribute to the environmental objectives of this Directive*" (Directive/2000/60/EC). The 2007 Commission Communication on Water Scarcity and Droughts included options related to "*putting the right price tag on water*", "*allocating water more efficiently"* and *"fostering water efficient technologies and practices*" (European Commission, 2007).

The Water Conservation Regulations (S.I. No. 527 of 2008) were introduced in 2007 to prescribe a set of forms for issuing notices under the Water Services Act 2007 relating to the restriction of water in certain circumstance (Figure 29). Section 56 states three such instances in which an authorised person may take corrective action or limit consumption of water where it is deemed to be being used wastefully (Irish Statute Book, 2007). Furthermore, it states that a water service authority may, for a specified period, restrict or prohibit certain classes of use, including use at specified times of day, to address a serious deficiency of water availability (Irish Statute Book, 2007).

In Ireland in 2009, the Renewed Programme for Government stated the intention to, "*Introduce charging for treated water use that is fair, significantly reduces waste and is easily applied. It will be based on a system where households are allocated a free basic allowance, with charging only for water use in excess of this allowance…. [and] Local Authorities will set their own rates for water use*." (Cowen and Gormley, 2009. p.5). The introduction of a scheme of water charges was proposed in the National Recovery Plan 2011-2014 whereby it was suggested that "*the introduction of a scheme for the metering and charging for domestic water… will lead to significant capital and current savings to the Exchequer and the General Government Sector over the medium term."* (Government of Ireland, 2010, p.77). The plan stated that water pricing would introduce a new revenue stream to meet its costs, which had been in the region of €590 million in 2008, and that the "*incentive effects of the metering system [would]… reduce demand to economically efficient levels*" (Government of Ireland, 2010, p.78)

In 2013, the Water Services (No.2) Act established domestic billing and a new semi-state company – Irish Water – to take over responsibility for the management of water services (Figure 29). Following a public consultation process in 2014, Irish Water's charges plan was approved based on volumes used and a free allowance (Irish Water, 2014). This scheme was revised, after a period of nationwide protest (Clinch and Pender, 2019), and a new scheme of charges was announced in the Water Services Act 2014 with reduced prices and a cap on bills (Clinch and Pender, 2019). In 2015, the Government introduced a €100 Water Conservation Grant for all households registered with Irish Water, promoting household expenditure on water conservation measures. No audits were held regarding the use of this grant which was suspended in 2016, and no further grants to enable domestic water conservation measures have been introduced since (Rolston, 2020). Alongside this, public protests continued around the installation of water-meters and the charging scheme, and in May 2016, following a general election, a decision was taken to suspend domestic water charging pending a review of the system by an expert commission (Expert Commission on Domestic Public Water Services, 2016). General domestic charges for water services were abolished with immediate effect in 2017 and funding of water services reverted to general taxation (Clinch and Pender, 2019).

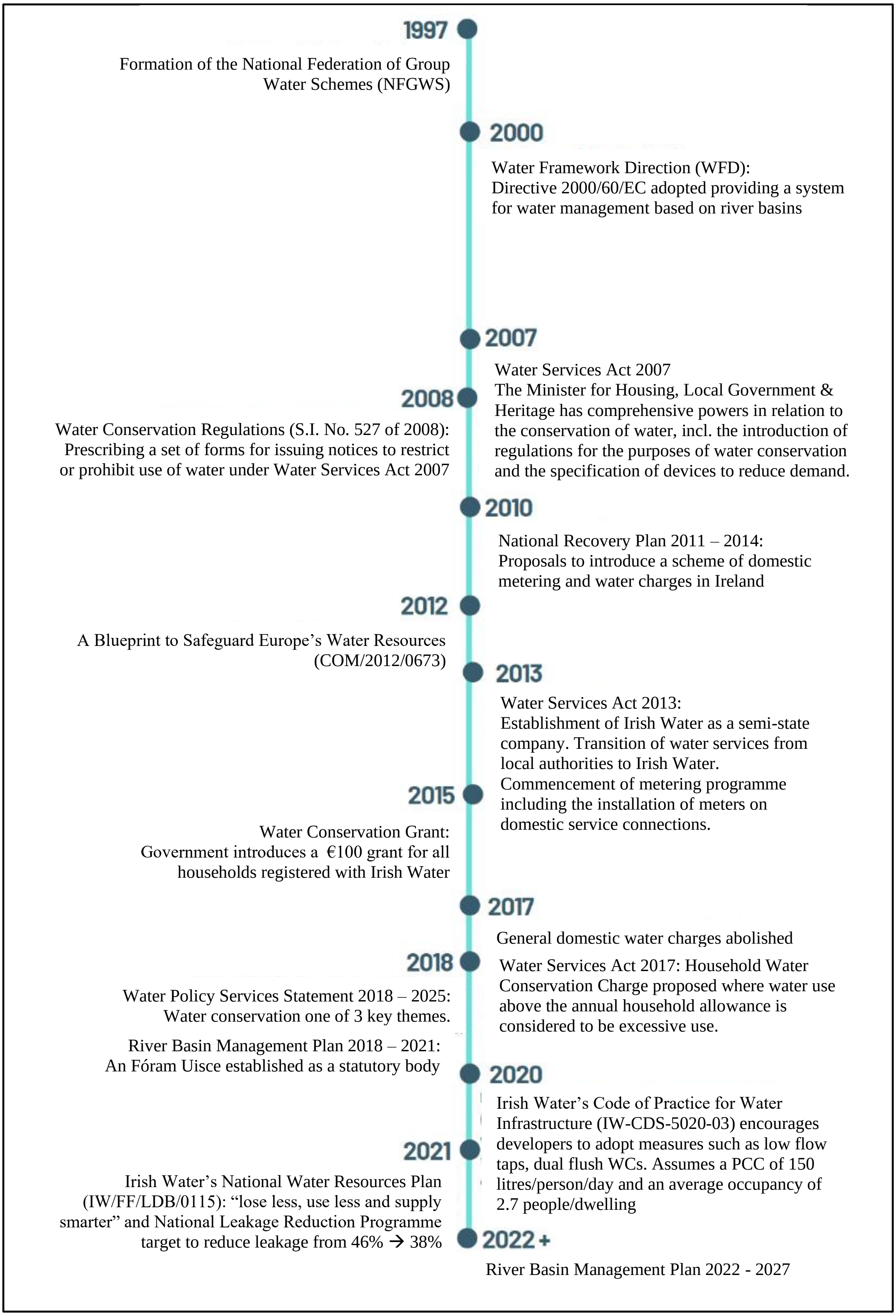


Figure 29 Timeline of live and historic water conservation policy and regulation in Ireland.

Conservation was one of three key themes set out by the Government in its Water Services Policy Statement 2018–2025 (Government of Ireland, 2020b), the first policy statement prepared under the amended Water Services Act of 2017 (Irish Statute Book, 2017). The plan stated that Irish Water must prepare a Strategic Funding Plan within three months of the publication of the Policy Statement, setting out its proposed operational and capital expenditure for the period up to 2025 (Government of Ireland, 2020b). The Household Water Conservation Charge (Citizens Information, 2021) set into legislation that water use above the annual household allowance (213,000 litres) would be considered excess use, and customers would be liable for excess use charges of €1.85 per 1000 litres on anything above this level (Figure 30). The annual household allowance is set at 1.7 times the average annual household usage of 125,000 litres. The level of charging for excessive use is set by the economic regulator (CRU). There was a period of direct engagement with affected households in advance of charging (Figure 30).

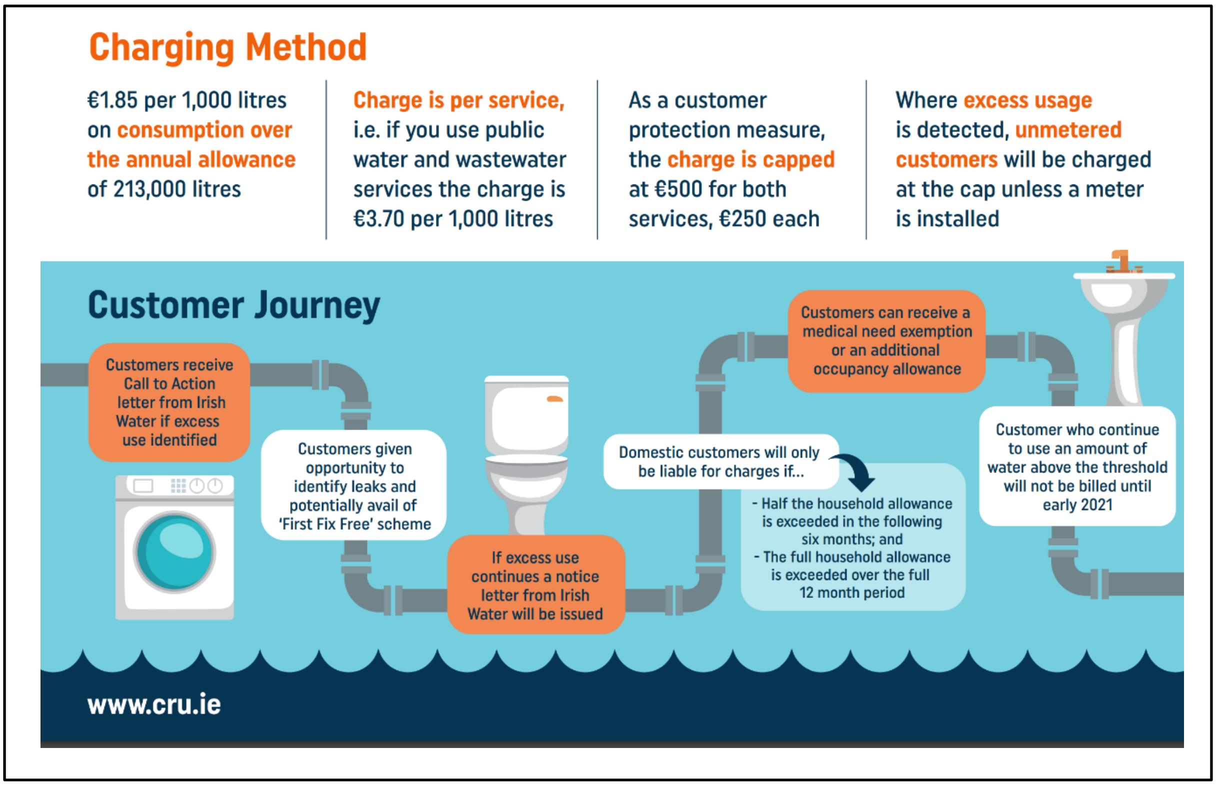


Figure 30 Water Conservation (Excess Use Charge) Decision infographic (CRU, 2019)

Irish Water introduced a free repair scheme, "First Fix Free" to enable the identification of customer side leaks (Irish Water, 2021) (Figure 30). The savings associated with the First Fix Free scheme are estimated to be 120Ml/d (gross leakage savings) to date (Irish Water, 2021) but this does not necessarily equate into reductions in overall demand due to the natural rate of rise (i.e. the rate at which leakage would increase if it is not managed) and new leaks occurring within properties or on other supply pipes (Irish Water 2021). The First Free Fix Scheme is one of seven approaches in Irish Water's Leakage Reduction Programme which also includes finding and fixing leaks in public area, mains replacement, pressure management and the establishment of district meter areas (DMAs) (Irish Water, 2019c). In 2019, Irish Water estimated their baseline leakage to be 741Ml/d, but there is potential for variability on this value due to the lack of certainty on customer consumption data (Irish Water 2021). The 25-year demand forecasts in Irish Water's National Water Resources Plan (NWRP) are based on an increase in domestic water use from significant population growth; an increase in non-domestic water use from economic growth; and large reductions in leakage (Irish Water, 2021). In 2018, the rate of leakage nationally was 46%, and following a €500 million investment, Irish Water intend to reduce this to 38% by the end of 2021 (Irish Water, 2019c).

Irish Water's NWRP aims to ensure that a reliable supply is available across the country to meet the economic, environmental and social needs of the whole population (Irish Water, 2021). The Plan proposes a 3- pillar approach to water management: *'lose less, use less and supply smarter'*. It refers directly to '*reducing water use through efficiency measures'* (Irish Water, 2021, p.119) to account for growth in demand arising from a static per-capita consumption rate (due to falling household occupancy) and expected population growth (of 50% by 2040) in several Irish cities including Cork, Galway and Limerick (Irish Water, 2021).

Finally, building regulations are a key part of domestic water conservation policy. Building regulations apply to the design and construction of a new building or an extension to an existing building. The minimum performance requirements that a building must achieve are set out in the second schedule to the building regulations (Government of Ireland, 2017). In Ireland, there are 12 parts to these requirements classified as Parts A to M. The parts that are relevant to water include:

- Part G (S.I. No. 335/2008) - Hygiene
- Part H (S.I. No. 561/2010) – Drainage and Wastewater Disposal and
- Part L (S.I. No. 292/2019 - European Union (Energy Performance of Buildings) (No.2) Regulations 2019) – Conservation of Fuel and Energy (Government of Ireland, 2017)

Part G states that "*sanitary conveniences shall be of such design as to facilitate efficient use of water for flushing*", and in Part L, water is only referred to in relation to the energy efficiency of water heating systems, suggesting the in new builds, the nearly net zero energy requirements could be met by, "*providing and commissioning energy efficient space and water heating systems with efficient heat sources and effective controls*". Irish Water's Code of Practice for Water Infrastructure (Irish Water, 2020) suggests "*Developers, in the interest of water conservation, are encouraged to adopt water conservation, including the use of dual flush water cisterns, low flow taps etc.*" but this is advisory and not supported by specific targets. Therefore it remains at the discretion of the owner whether or not to incorporate them.

2.3 Potential regulatory mechanisms

There are a variety of ways in which stronger mechanisms could be deployed across national policy to improve domestic water conservation, including the use of:

- revised building regulations with minimum standards for appliances, fittings and products, or
- a labelling / rating scheme linked with energy efficiency

2.3.1 Building regulations and minimum standards for fittings and products

There is the potential for the expansion of the Part G (Hygiene) or Part L (Conservation of Fuel and Energy) of the Irish building regulations to specify further measures for water conservation. Part L currently refers to the fitting of flow restrictors on hot water systems, but does not specify maximum ratings for hot water-using fittings and appliances such as taps, showers, washing machines and dishwashers. An example of how this could be done could be taken from Approved Document G building regulations in England and Wales (HM Government, 2015), which provides specific guidance on the supply of water to a property including targets for water efficiency (Planning Portal, 2016).
Generally, there are two approaches for setting levels or targets for water use:

- component level targets, specifying the flow rate of individual fixtures and fittings; and
- whole-building outcomes, specifying the total water use of the building (WRAP, 2010).

Approved Document G in England and Wales adopts a hybrid approach, including a requirement that "*reasonable provision must be made by the installation of fittings and fixed appliances that use water efficiently for the prevention of undue consumption of water*" and that new dwellings must not exceed 125 litres per person per day or in some cases 110 litres per person per day (Planning Portal, 2016). The estimated water consumption of a new dwelling should be calculated using the water efficiency calculator for new dwellings method, or a fittings approach in which the water consumption of fittings provided must not exceed the following values (HM Government, 2015):

Table 3 Maximum fittings and appliance ratings for Approved Document G building regulations in England and Wales.

Fitting/Fixture	**125 litres/person/day**	**110 litres/person/day**
	Maximum fitting consumption	
WC	6/4 litre dual flush 4.5 litre single flush	4/2.6 litre dual flush
Shower	10 litre/minute	8 litre/minute
Bath	185 litre capacity	170 litre capacity
Dishwasher	1.25 litre/place setting	
Washing Machine	8.17 litre/kilogram	
Sink taps	8 litre/minute	6 litre/minute
Basin taps	6 litre/minute	5 litre/minute

The values in the English building regulations (Table 3) are broadly comparable with the LEED fixture and fitting code requirements in the US and Canada, which specify a maximum rating of 6 litres per flush for WCs, 8.3 litres per minute for kitchen sink and basin taps, and 9.5 litres per minute for showerheads (USGBC, 2019). No such fittings standards exist in the corresponding Irish building regulations. The maximum ratings specified in Approved Document G building regulations in England and Wales (Table 3) generally equate to a BREEAM performance level of 2 – 3 across the different component types (Figure 31). The levels (which range from a baseline to level 5) reflect levels of typical, good, best and exemplary practice (BREEAM, 2020a).

Component	Performance Levels (quoted numbers are minimum performance required to achieve the level)						
	Base	1	2	3	4	5	Unit
WC	6	5	4.5	4	3.75	3	Effective flush volume (litres)
Wash hand basin taps	12	9	7.50	4.50	3.75	3	litres/min
Showers	14	10	8	6	4	3.50	litres/min
Baths	200	180	160	140	120	100	litres
Urinal (2 or more urinals)	7.50	6	3	1.50	0.75	0	litres/bowl/hour
Urinal (1 urinal only)	10	8	4	2	1	0	litres/bowl/hour
Greywater/ rainwater system	0	0	0	25	50	75	% of WC/urinal flushing demand met using recycled non-potable water
Kitchen tap: kitchenette	12	10	7.50	5	5	5	litres/min
Kitchen taps: restaurant (pre-rinse nozzles only)	10.30	9	8.30	7.30	6.30	6	litres/min
Domestic sized dishwashers	17	13	13	12	11	10	litres/cycle
Domestic sized washing machines	90	60	50	40	35	30	litres/use
Waste disposal unit	17	17	0	0	0	0	litres/min
Commercial sized dishwashers	8	7	6	5	4	3	litres/rack
Commercial/ industrial sized washing machines	14	12	10	7.50	5	4.50	litres/kg

Figure 31 Water consumption levels by component type (from BREEAM, 2020a)

Where significant reductions in whole-building outcomes are required (i.e. at or below 110 litres/person/day), homeowners and developers may need to go beyond water-efficient devices such as low flush toilets or low flow showerheads (Balinger and Stephenson, 2020). Research by Water UK with Artesia Consulting suggested that a maximum technical reduction in PCC to 85 litres/person/day is possible in the UK by 2050. They suggested a feasible target of 100 litres/person/day by 2050, if the "*government acted robustly*" (Water UK, 2019a). They found that without changing building regulations, it would not be possible to cost effectively reduce household consumption below 110 - 115 litres/person/day (Water UK, 2019a). To achieve reductions below this, it is likely that policy mechanisms such as mandatory water labelling and building regulations, alongside technologies for rainwater harvesting and grey water recycling. In 2015, the Cabinet of Japan approved regulation to achieve widespread rainwater harvesting in newly constructed state government or incorporated administrative agency buildings through the Act to Advance the Utilization of Rainwater (Japan for Sustainability, 2015; Waterwise, 2017). This legislation specifies the owner of the building is required to install a rainwater harvesting system as a general rule, if there is usable space for such a system to be constructed.

At a domestic level, one of the key drivers for rainwater recycling in the UK was the Code for Sustainable Homes ((Department for Communities and Local Government, 2010). Following a Housing Standards Review (Bre, 2019), the Code was by replaced by national technical standards and building regulations including Approved Document G in England and Wales, amongst others. In the absence of specific policy and regulatory drivers, such technologies are unlikely to be widely taken up due to market barriers such as capital cost, lack of customer interest, and public perception of disruption during the installation process (Ballinger and Stephenson, 2020).

More recently, the focus on water neutrality (Earl, 2021) or net-zero water buildings (U.S. Department of Energy, n.d.) – which rely substantially on the use of alternative water sources to reduce the demand for potable water – provide renewed policy drivers for implementing rainwater harvesting or grey water recycling. Irish Water has a remit to deliver secure, reliable and sustainable long-term water supplies which facilitate domestic and economic development (Irish Water, 2021). Research and consultations undertaken by Irish Water and Dublin City Council have concluded definitively that existing water supply sources do not have the capacity or resilience to meet future requirements of homes and businesses in Dublin and the midlands (Irish Water, 2021). The Irish population is expected to increase by 21% over the next 25 years. Under the Housing for All Plan and Project Ireland 2040 strategy projections there will be a need for 300,000 new homes by 2030 (Government of Ireland 2021a) and 500,000 new homes by 2040 (Government of Ireland, 2018, Government of Ireland, 2021b). Forthcoming abstraction legislation, required to ensure Ireland can meet its obligations in the Water Framework Directive, may reduce the amount of water that can be withdrawn from rivers and groundwater aquifers in the future (Irish Water, 2021). Capacity issues in the water and sewerage networks, and restrictions on the volume of water that can be extracted from the environment, has already led to delayed delivery of ongoing developments and questions over the viability of new housing required to meet population growth and Government efforts to boost regional development (Houses of Oireachtas, 2021).

Similar problems have been seen in the UK where population growth is substantial in regions where the water supply is under severe pressure (Pressly, 2012). Despite this, development continues and water companies are legally bound to supply such new developments, regardless of concerns about sustainability. Analysis by the Environment Agency suggests that relatively small changes in per capita consumption could be considerably influential in determining future ability to meet water needs, and to reduce rates of abstraction to a sustainable level (Water UK, 2019). A recent example involved significant concerns over groundwater abstraction (and increase in abstraction required to serve planned development) at Hardham in West Sussex (JBA, 2021). Natural England advised that it could not say with any certainty that the levels of abstraction were not having an adverse impact on water levels, water quality, and the natural habitats and advised the local councils that any future or planned development must not add to this adverse effect. Water neutrality was proposed as a potential means to allow development to proceed without increasing abstraction (JBA, 2021) relying on a package of measures (JBA, 2021). The measures included:

- water audits – i.e. household visits to provide advice on the efficient use of water and to fit water saving devices
- an expansion of Southern Water’s leakage reduction programme above their business plan
- an extension to the metering programme, with a faster rate of adoption of smart meters
- adoption of rainwater harvesting or grey water recycling in new builds
- retrofitting of rainwater harvesting or grey water recycling in existing housing (JBA, 2021).

2.3.2 Rating scheme linked with energy efficiency or carbon targets

An alternative approach would include: (i) the possibility of integrating within energy efficiency regulations such as the Building Energy Ratings Certificate (BER) or (ii) creating a standalone label or rating scheme (as discussed in section 3).

BER rates the energy performance of a home on a scale between A and G, whereby A-rated homes are the most energy efficient and G-rated are the least (SEAI, 2017). Calculating the energy performance of a building is a legal requirement, as specified in Directive 2002/91/EC. The methodology for calculating building energy performance may differ at a regional scale, but should follow a common approach on the basis of objective criteria, to enable transparency in comparisons of energy performance across the market (Directive 2002/91/EC). In Ireland, the BER certificate is calculated based on the amount of energy the home requires for space and hot water heating, ventilation and lighting. The calculation uses the Dwelling Energy Assessment Procedure (DEAP), which is based on IS EN 13790.

The process of abstracting, pumping, treating and heating water consumes energy and releases greenhouse gas emissions (Waterwise, 2021). At a PCC of 138 litres/person/day, the amount of carbon emissions arising from the supply of water, its use in the home, and the collection and treatment of wastewater amounts to more than 2.6 kg-CO2e per property per day. The largest contributors to this is heating water in the home for appliances and personal bathing (Waterwise, 2021). SEAI estimated that 19% of the 18.5 MWh of energy used in an average Irish home in 2016 was due to heating water (SEAI, 2018). If per capita consumption was reduced by just 20% to 110 litres/person/day, the saving per property would be 0.45 kg-CO2e per property per day. This is equivalent to the carbon emissions generated from driving 1.1 miles (0.7km) in a typical passenger vehicle (U.S. EPA, 2021a). A more substantial reduction (e.g. 40%) to the former Code for Sustainable Homes' most ambitious target of 80 litres/person/day could save more than a third of all water-related emissions (Waterwise, 2021). If the 500,000 new houses required for Project Ireland 2040 targets were built using water neutral principles, they could save around 450,000 tonnes of CO2e/year based on the typical emissions for the supply, treatment and use of water in the home (Waterwise 2021; Earl, 2021). This value is equivalent to the carbon dioxide emissions released from the use of more than 190,000 litres of gasoline; 1000 barrels of oil; or charging 55 million smart phones (U.S. EPA, 2021a). There is therefore an argument for greater integration between water and energy efficiency, perhaps adopting a whole-house efficiency approach (Waterwise, 2021) through integration of water efficiency in the BER certificate.

2.4 Best practice in water efficient buildings

The Code for Sustainable Homes is an historic example of best practice in buildings to promote water conservation. The Code sought to "*reduce the consumption of potable water in the home from all sources, including borehole well water, through the use of water efficient fittings, appliances and water recycling systems*." (Department for Communities and Local Government, 2010, p.82). It involved the use of a Water Efficiency Calculator to assess water efficiency in new dwellings in support of the 2009 Approved Document G building regulations in England and Wales. The calculator enabled the contribution of each internal fitting (micro-component) to be determined. Flow restrictors, low flush WCs, and rainwater recycling can be built into the assessment provided they are fixed fittings and fixtures. Devices that can be retrofitted to WCs, such as cistern displacement and flushing reduction, were not recognised by the Code as they could be easily removed (Department for Communities and Local Government, 2010, p.82)

North West Bicester was the UK's first "Eco-Town", constructed in line with the high sustainability standards outlined in the UK Government's Eco-Towns Planning Policy Statement, 2009. It was designed to be a zero carbon development, adhering to the Code for Sustainable Homes level 5, with low water use (80 litres/person/day), achieved through the inclusion of rainwater harvesting, multi-stage sustainable drainage (SuDS) systems (including green roofs and soakaways) and in-home information showing electricity and water usage (Reed, n.d.). The development was awarded 'One Planet Living' status, acknowledging it's meeting of ten principles on aspects of social, environmental and economic sustainability (Reed, n.d; Bioregional, n.d.)

Furthermore, a separate study assessed the utility performance (water, electricity and heat) of 25 houses in a Bre EcoHomes Excellent certified development in the UK (Gill et al., 2011). The development exceeded the requirements of UK Building Regulations (Gill et al., 2011). Water consumption was 39% lower than the national average, with a PCC of 91.5 litres/person/day. This site was close to achieving the second most ambitious target (level 4, 90 litres/person/day) (Gill et al., 2011). Water savings could be partially attributed to the installation of rainwater harvesting, which was used for toilet flushing and garden irrigation, offsetting approximately 24 litres/person/day in 2009. However, the variation between maximum and minimum consumers of water was the most significant of all utilities (i.e. water, electricity, heat). This suggests that strict targets for per capita consumption (such as those seen in Code for Sustainable Homes) may be difficult to achieve through low flow fixtures and rainwater harvesting alone, if there is not also complementary behavioural change and awareness amongst those using the fixtures and fittings (Gill et al., 2011).

There is arguably greater potential to apply technologies for water conservation to multi-household domestic properties, such as apartments. In Australia, around 15% of households live in apartments (NABERS, 2020). By comparison, around 12% of the Irish population lived in apartments in 2016, but there is considerable regional variation across the country; 35% of households in Dublin city reported to live in apartments (CSO, 2021). The NABERS Scheme in Australia rates the environmental performance (including energy, water, waste and indoor environment) of multi-occupancy buildings, such as hotels, apartments, and offices, on a six star scale. High performing buildings, on average, have higher investment returns than poorer performing buildings and water and energy costs can be reduced by as much as 30% (NABERS, 2020). The NABERS water rating covers all the water used throughout the building. A four star water rating might include the use of high efficiency fittings and a small rainwater tank, whereas a 5 star rating could include waterless urinals, and a 5.5 star rating could include black water recycling (Lee et al., 2017). However, the technologies required to achieve some of the higher ratings (i.e. 5.5 and above) can result in a trade-off between water and energy: some of the most energy efficient methods of cooling are responsible for a significant use of water, and some of the water recycling processes are energy intensive (Lee et al., 2017). In Romania, the Vox Vertical Village, which is currently under development and shortlisted for the BREEAM 2021 Awards, is designed to use a complex building management system (BMS) to monitor water consumption and detect customer side leakage (BREEAM, 2020b) The development will also include an efficient irrigation system, based on humidity sensors, drip-feed irrigation, zoning and plant selection, to significantly reduced the unregulated water consumption (BREEAM, 2020b).

Finally, whilst not a domestic property, the Grangegorman strategy at Dublin Institute of Technology is designed to use net zero mains water by 2050, through the adoption of Sustainable Drainage Systems (SuDS), grey water and rainwater harvesting systems and water-efficient devices such as spray water taps, dual flush WCs, water metering and mains leak detection (Grangegorman Development Agency, 2014; Grangegorman Development Agency, n.d)(Figure 32). The intention is to reduce mains water consumption by 60%. To achieve this goal, a series of targets are mapped out from a 2017 baseline to reduce water consumption from

1.5m^3/person/year in 2017 to 0.6 m^3/person/year in 2050; to increase the amount of recycled non-potable water used for WC / urinal flushing from 25% in 2017 to 55% in 2050; and to use collected rainwater for sports pitch irrigation (meeting 55% of the irrigation demand with rainwater by 2050) (Grangegorman Development Agency, 2014).

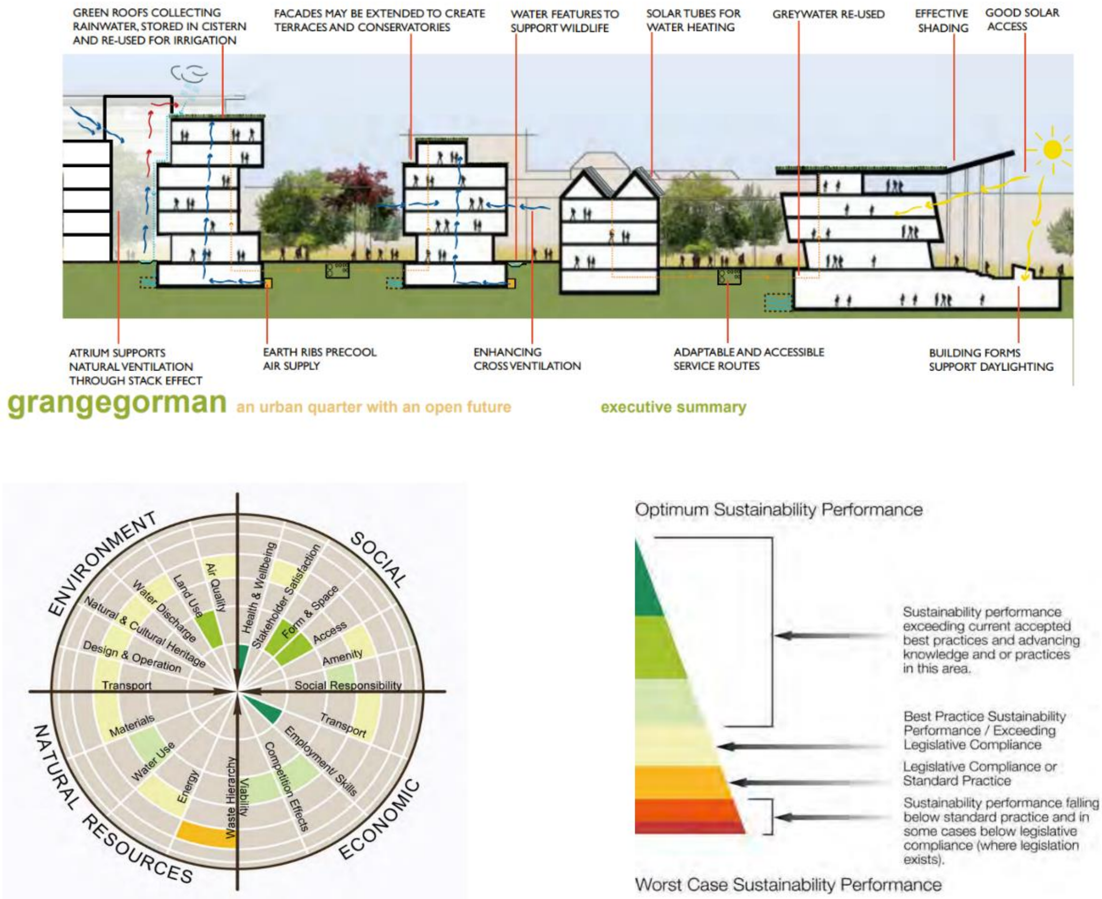


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Figure 32 Grangegorman masterplan summary of water-related features and sustainability performance (Grangegorman Development Agency, n.d)

3. Water efficiency labelling

Water efficiency labelling refers to programmes that provide a rating or an indication as to whether the amount of water used by fittings and appliances is efficient (Energy Saving Trust, 2019). The purpose of such programmes is to encourage consumer choice towards more water efficient appliances. As such, labelling schemes are often integrated with programmes such as building regulations or incentives (Energy Saving Trust, 2019). The UN High Panel on Water state: "*The replacement of inefficient taps, toilets, showerheads, washing machines, and dishwashers with more efficient models can have significant effects on water consumption in the home, reducing per capita consumption significantly*" (United Nations, 2017).

A study in 2019 found that there are 18 places internationally with a water efficiency labelling scheme in place: four of which have mandatory schemes (Australia, New Zealand, UAE and Singapore) and 14 of which are voluntary schemes (Figure 33) (Burton et al., 2019). Since the report was written, the UK Government announced intentions to make regulations to introduce a mandatory water efficiency label in July 2021 (UK Parliament, 2021).

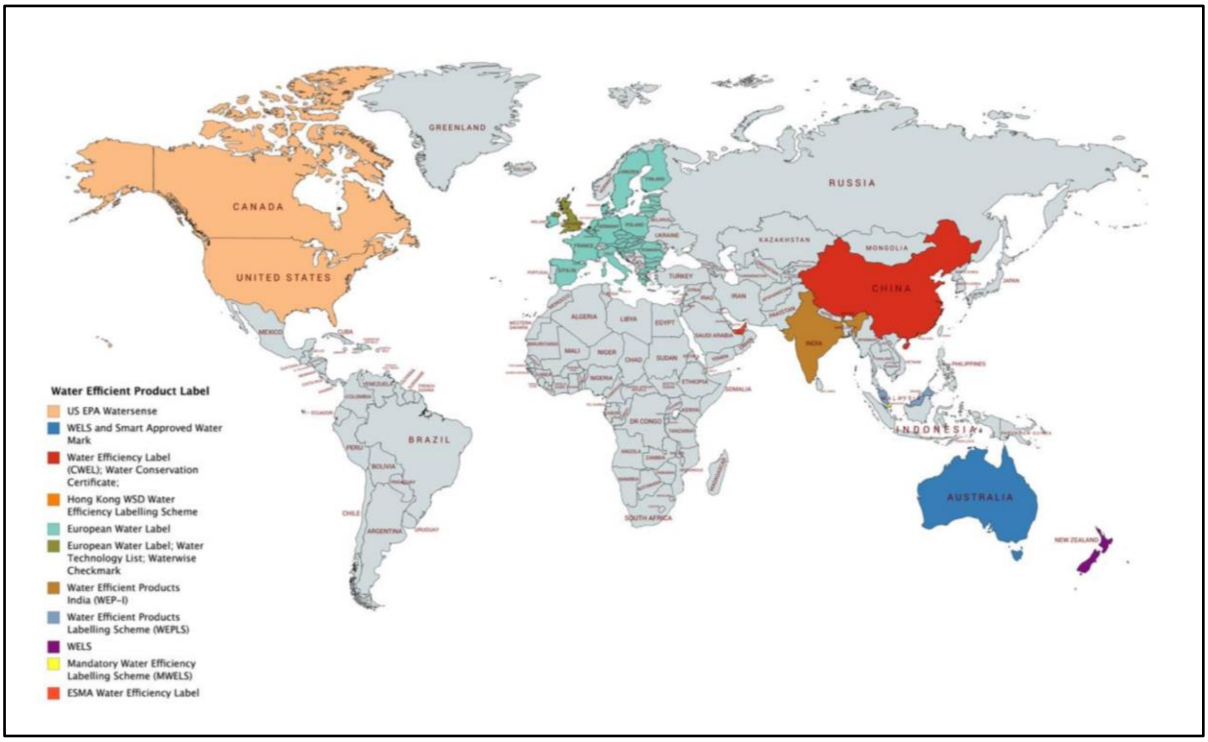

Figure 33 International coverage of water efficiency product labelling including mandatory and voluntary schemes (Burton et al., 2019).

3.1 International Examples

Brief case studies are provided below for three mandatory schemes – (i) the newly implemented UK Government-led water efficiency label; (ii) the Australian and New Zealand Water Efficiency Labelling Scheme and (iii) the Singapore Mandatory Water Efficiency Labelling Scheme – and two voluntary schemes – the USA's and Canada's WaterSense; and the EU Water Label.

3.1.1 United Kingdom

The Waterwise Checkmark (Figure 34) was first implemented in 2006, covering all products with water efficient technology at their core. It is a voluntary, NGO-led scheme which is linked with the EU water label (section 3.1.5). However, following a consultation on measures to reduce personal water consumption in 2019, the UK Government announced measures to make regulations to introduce a mandatory, government-led water efficiency label in July 2021, linked with building regulations and fittings standards (UK Parliament, 2021). Consultation will take place throughout 2022, between two Government departments - the Department for Food and Rural Affairs (Defra) and the Department for Business Energy and Industrial Strategy (BEIS) – reflecting the impact of water efficiency on the ability to achieve carbon neutral targets (Reynolds, 2021). The intention is that the label will inform and encourage consumers to purchase more water efficient products for both domestic and business use. The legislation is expected by 2024 (Reynolds, 2021). Furthermore, the statement set out the intention to encourage local authorities to adopt the optional minimum building standards of 110 litres/person/day in all new builds, and to develop a roadmap towards greater water efficiency, including revised building regulations and the development of new technologies (UK Parliament, 2021).

Figure 34 Waterwise Checkmark (UK)

3.1.2 Australia and New Zealand

Australia has a long history of water conservation and regulation. Water efficiency labelling began in the 1980's, branding shower heads and dishwashers with an A or AA rating (Burton et al., 2019). A mandatory Water Efficiency Labelling and Standards (WELS) Scheme (Figure 35) and voluntary Smart Approved WaterMark (SAWM) were established in the 2004 National Water Initiative (Burton et al., 2019). The mandatory WELS scheme, implemented in 2005, sought to conserve water supplies by reducing water consumption; deliver information for purchasers of water-using and water-saving products; and promote the adoption of efficient and effective water-use and water-saving technologies (Burton et al., 2019). All products regulated by the scheme and supplied in Australia are required by law to be tested for water consumption, registered with WELS and labelled in accordance with the WELS standard.

Figure 35 Australian Water Rating

The label (Figure 35) includes a star rating, which enables quick comparison between different products; the rate of water consumption (e.g. flow rate, litres per flush etc) to enable users to estimate how much water the product will use in their home; and finally the registration and product details, such as the licence number and cycle used for testing (Australian Government, 2017). Although New Zealand is wetter than Australia, there were two primary reasons for implementing the WELS shortly after Australia did in 2005. Firstly, the New Zealand Government responded to maintain regulatory harmony with Australia to support the strong trading relationship between the two countries. Secondly, whilst the risks are not as severe as those seen in Australia, New Zealand also suffers from a lack of water supply security (Ministry for the Environment, 2005). To prevent supply restrictions, particularly in summer, water efficiency labelling was implemented to reduce the need for increasing supply capacity (Ministry for the Environment, 2005).

3.1.3 Singapore

The Singapore Mandatory Water Efficiency Labelling Scheme (MWELS) (Figure 36) is a mandatory, government-led scheme, which was introduced in 2009 (Burton et al., 2019). It is based on a four-tick rating system (Figure 30), whereby a larger number of ticks denotes a more water efficient product. To complement MWELS, minimum water efficiency standards were created for water fittings. Originally, this was set at a 1-tick threshold. However, since 2019, PUB mandated that all water fittings must meet a minimum of 2-ticks in all new and existing domestic premises undergoing renovation (Burton et al., 2019). The impact of the scheme can be seen in two ways. Firstly, the sales of 3-tick washing machines has increased substantially since the scheme's implementation, indicating a change in consumer behaviour and an increased desire to purchase efficient devices (Burton et al., 2019). Secondly, per capita consumption in Singapore has decreased from 165 litres per person per day in 2003, to 143 litres per person per day in 2017. PUB has a target of 140 litres PCC by 2030.

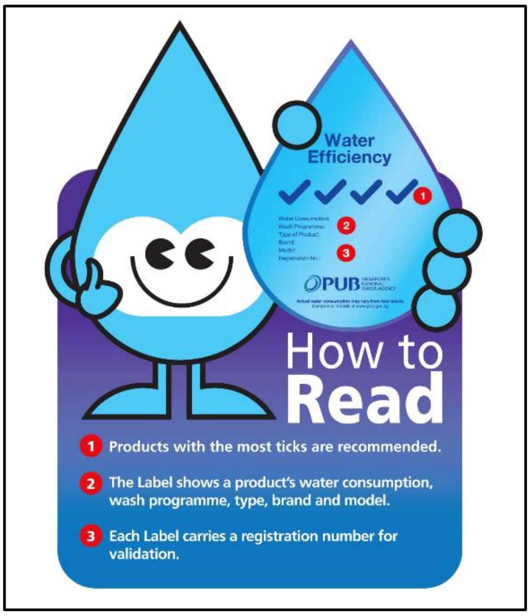

Figure 36 Singapore Water Efficiency Label

3.1.4 USA and Canada

WaterSense, implemented in the USA and Canada in 2006, covers taps, showerheads, toilets, flushing urinals, and weather-based irrigation controllers amongst others (Figure 37) (U.S. EPA, 2021b). There are over 27,000 products registered with the scheme (Burton et al., 2019).

Figure 37 WaterSense Quality Mark and the product categories it covers

It is a voluntary, government-led scheme, reviewed and supported by the US Environmental Protection Agency (EPA). It is a quality mark, rather than a rating scheme, and to achieve the quality mark products must use ~20% less water than a standard item. Each item has a specification, efficiency and performance requirements, and a required test protocol, and applicants need independent, third-party certification to confirm their product meets the WaterSense criteria. The scheme cost in the region of $33m (to the US EPA) between its launch and 2017, but has led to savings of more than 4.5 million megalitres of water, 284 billion kWh of energy, and $46.3 billion in consumer water and energy bills (Burton et al., 2019).

3.1.5 European Union

The Water Label was introduced in 2011, based on the UK water label, and it is a voluntary, industry-led scheme. It also now aligns with other schemes in European countries, such as the Portugese ANQIP scheme and the Swedish and Swiss energy labels (Burton et al., 2019). To register with The Water Label, companies are asked to sign a "Declaration of Conformity" and submit copies of certifications of compliance and test reports. Registration lasts for one year. The label is based on a series of performance bands – as seen with energy efficiency – for the water consumption performance of the product. The energy consumption per year and other technical features are provided on the label Figure 38). There are almost 10,000 products registered with the EU water label.

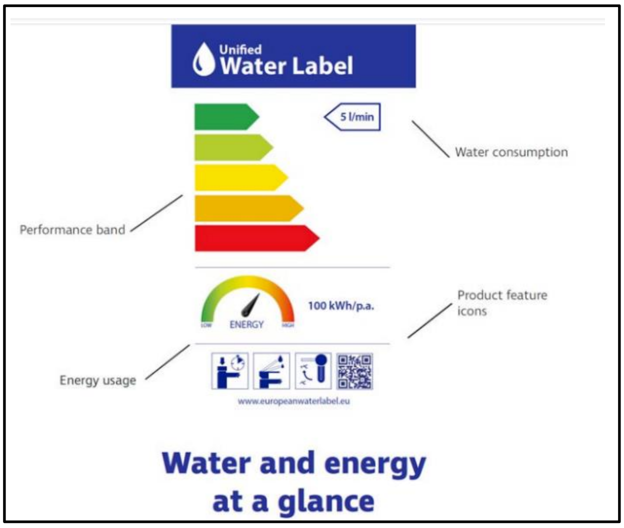

Figure 38 The EU Water Label

3.2 Implementation

An independent review of the potential impact a water labelling scheme could have on domestic water consumption in the UK was conducted in 2019, seeking to identify the most impactful and cost effective options (Energy Saving Trust, 2019). Following an assessment of international best practice in water labelling schemes and activities a series of scenarios was developed and cost benefit analysis was undertaken to identify the most preferable policy option (Energy Saving Trust, 2019). Data was gathered from existing water labels, together with information about likely product performance and availability, and used to predict uptake of more efficient products over time. This was used to project water, financial and carbon savings. Implementation costs were projected based on data from equivalent initiatives (Energy Saving Trust, 2019).

Seven scenarios were considered in the study (Table 4). Scenario 3 was deemed to be unrealistic and difficult to model, and subsequently dropped from further analysis (Energy Saving Trust, 2019). Scenario 6 was considered the business as usual (BAU) case, as at the time of writing there was a voluntary water label for the UK and the rest of Europe, led by the water fittings industry (see section 3.1.5).

Two of the scenarios (2 and 5) are linked to building regulations, such that builders can demonstrate compliance with the regulations by specifying labelled products of a certain rating when fitting out new properties. Scenario 2 is also linked to incremental minimum standards for water using fittings and appliances (e.g. changes to The Water Supply (Water Fittings) Regulations 1999), such that only products above a certain label rating can be sold, whether for new build or retrofit. The scenario assumes that these minimum standards would be phased in over a ten year timespan. Scenario 7 is as per the current scheme, but with an intensive marketing initiative to raise awareness, market penetration and visibility of the label.

Table 4 Scenarios for cost benefit analysis of water efficiency labelling schemes in the UK (Energy Saving Trust, 2019)

	Delivery mechanism	Delivery agency	Association with other schemes	Notes
1	Mandatory	Government-led	No association	Baseline scenario
2	Mandatory	Government-led	Associated with Building Regulations **and** minimum standards	
3	Mandatory	Government-led	Associated with consumer incentives	
4	Voluntary	Government-led	No association	Baseline scenario
5	Voluntary	Government-led	Associated with Building Regulations	
6	Voluntary	Industry-led	No association	Baseline scenario – also BAU case
7	Voluntary	Industry-led	Associated with intensive marketing	
8	Voluntary	Industry-led	Associated with requirements for funding	

The results of the study revealed that scenario 2 performed the best across all five metrics – including (i) cost per million litres saved; (ii) average incremental social cost; (iii) water saved per person (10 years); (iv) water saved per person (25 years); and (v) cost : benefit ratio – followed by scenarios 1 and 5 (Energy Saving Trust, 2019). A number of assumptions were made in carrying out the analysis, and as such, there is uncertainty around the exact costs and savings that a label could generate (Energy Saving Trust, 2019). However, the sensitivity analysis suggests that the ranking of the scenarios is not sensitive to variations in the assumptions made, and the recommendation for a mandatory government-led scheme linked to building regulations and minimum standards remains the best option.

3.2.1 Delivery Mechanism

A review of Product Stewardship and Water Efficiency Labelling for New Zealand suggested that regulation is only intended as a backstop when voluntary schemes do not deal with significant problems in product stewardship issues (Ministry for the Environment, 2005). Regulation is preferred when:

- There is no effective voluntary action, and without it none is likely,
- The benefits of regulation outweigh the costs, or
- The waste (arising from a lack of action) is causing significant adverse effects on economic well-being, biodiversity, human health, and/or water quality (Ministry for the Environment, 2005).

Mandatory labelling schemes tend to have a higher uptake than voluntary schemes (Burton et al., 2019) and produce larger water savings (Energy Saving Trust, 2019). The most successful voluntary schemes, tend to be those that are government-led (Energy Saving Trust, 2019) and quality, rather than rating, focused (Burton et al., 2019). The US and Canada use the

WaterSense scheme, which is voluntary but has good market penetration and recognition by consumers. However, Hong Kong's scheme is also voluntary and government-led, but it started later than WaterSense, covers fewer product categories and uses a grading system (Burton et al., 2019). Another factor which could influence the success of a labelling scheme relates to application fees. Malaysia's WEPLS scheme is voluntary and government-led, as seen in the USA and Hong Kong. But, Malaysia's scheme charges a fee for applications, whereas the schemed in Hong Kong (WELS) and the US/Canada (WaterSense) do not. There is a possibility that removing the charge for applications in Malaysia could increase the uptake and success of the scheme (Burton et al., 2019).

3.2.2. Delivery Agency

Voluntary schemes which are industry or NGO-led, tend to achieve a lower uptake than those which are government-led (Burton et al., 2019). This may be due to the resources available – it's possible that governments have more resources to dedicate to a scheme, or find it easier to allocate funding, in comparison to NGOs and industry (Burton et al., 2019) – or other factors. One exception is Portugal's ANQUIP scheme, which encountered notable success whilst being a voluntary and NGO-led project. One of the main contributors to the failure of eco-labelling scheme is a lack of public awareness, and therefore, good market presence, is deemed to be crucial to the success of the scheme (Burton et al., 2019). Whilst industry-led schemes, such as the European Water Label and China Water Conservation Certificate, also claim success, there is little or no evaluation of direct impact of these schemes (Burton et al., 2019). In the scenarios considered by the Energy Saving Trust, the top three scenarios, in terms of water savings likely to be achieved, were all government-led (Energy Saving Trust, 2019).

3.2.3 Links with other policy or regulation

Water efficiency labelling schemes drive market transition towards more water efficient products in two ways. Firstly, they encourage consumers to choose more efficient products, and secondly they push manufacturer innovation towards products which can deliver a higher water efficiency. These two processes eventually lead to inefficient products becoming phased out from the market (Burton et al., 2019). There are a variety of different ways in which countries implement complementary schemes to drive this transition further: ranging from customer rebates for purchasing water efficient products in Australia or a reduction in the fee associated with the label for more efficient products in the UAE (Burton et al., 2019).

The majority of the labelling schemes require any product within it to comply with national or ISO standards, but very few go beyond this to link to other regulatory schemes. One such example is within Australia's and New Zealand's WELS where white goods must also be registered with the Equipment Energy Efficiency program and the Australian energy label (Burton et al., 2019). Whilst there is a similar requirement for energy using appliances to display an energy label in the EU, there is unfortunately no overlap between water and energy labels for such product types. One potential route to implementing a water efficiency label may be to combine with the BER certificate.

Another option would be the development of a standalone, mandatory water label, as has recently been announced in the United Kingdom (July 2021). The existence of an industry-led, voluntary labelling scheme in Europe (the European Water Label) may not preclude the potential to implement a national mandatory scheme in Ireland, provided any newly adopted regulations comply with European Standards and legislation. Comparisons with a different labelling scheme (i.e. origin labelling of foodstuffs; Laaninen, 2018) suggest there may be potential for Member States to adopt additional national measures concerning mandatory labelling. Finally, two of the top three performing scenarios in the Energy Saving Trusts cost-benefit analysis involved an association with other schemes, such as building regulations or minimum fittings standards (Energy Saving Trust, 2019).

Regardless of the implementation mechanism, it is likely that a review of current product types, ratings, and testing methodologies will be needed, alongside a scheme to determine label rating matrices and minimum standards for each product. A review of product performance testing methodology and an approach, or software, to enable such methodologies to be enacted will subsequently be required. The technical documentation will need to be developed and any labelling obligations agreed. Finally, it will be important to design in some capacity for expansion and improvement in water label ratings, to account for innovation and product development, as seen in Singapore with the addition of a fourth tick (Burton et al., 2019).

3.3 Impact

The labelling schemes that have experienced more success, such as the Australian Water Rating (Australian Government, n.d.) or WaterSense, have conducted research to demonstrate the impacts the scheme has had in terms of annual water consumption; monetary savings; availability and accessibility of information for customers; market share of water efficient products; and greenhouse gas emission reductions (Burton et al., 2019). The cost of implementing these schemes is based on the scheme set-up and maintenance; the creation of a label, standards and requirements for each product; the development of agreed testing standards; and the monitoring and enforcement of the scheme, amongst others (Burton et al., 2019).

A cost-benefit analysis of seven scenarios for a water labelling scheme in the UK assumed a cost per million litres of water saved ranging from £380 in a government-led, mandatory scheme, to £1,369 in the ‘business as usual’ scenario, which is an industry-led, voluntary scheme (i.e. the European Water Label) (Energy Saving Trust, 2019). The largest water savings were seen in the government-led, mandatory scheme, which is expected to deliver reductions of 6.4 litres/person/day within 10 years, or 31.4 litres/person/day within 25 years (Table 5). A study by Water UK and Artesia in 2019 found that the single most cost-effective intervention to reduce per capita consumption is a mandatory government-led scheme to label water-using products, linked to revised building regulations and standards relating to water supply fittings. They estimated this could reduce consumption by an additional 31 litres/person/day by 2065 (Water UK, 2019b).

Table 5 Cost-benefit analysis of delivery strategy for water labelling (adapted from Energy Saving Trust, 2019)

Delivery Mechanism	Mandatory	Voluntary	Voluntary
Delivery Agency	Government-led	Government-led	Industry-led
Linked with	Building regs & min. standards	Building regs	N/A
Cost (£ per million litres saved)	380	418	1,369
PCC reduction in 10 years (litres/person/day)	6.3	2.2	0.3
PCC reduction in 25 years (litres/person/day)	31.4	9.3	1.3

A review of the environmental and economic impacts of the Australian WELS (Fane et al., 2018) found the scheme is responsible for an annual water saving of 112 gigalitres/year – equivalent to 21% of the water supplied to Greater Sydney (approx. 5 million people) – with the largest proportion of water savings coming from taps, followed by showers. The estimated energy savings from WELS are equivalent to more than 2.1 million barrels of oil (Fane et al., 2018). A cost-benefit analysis revealed the total cost of the scheme (including labelling, supplier costs and demand management strategies) was $644 million (Fane et al., 2018). However, the benefits (which included water and electricity savings) exceeded $5.6 million (Fane et al., 2018).

4. Water conservation incentives

This section explores monetary and non-monetary incentives for domestic water conservation. Domestic customers in Ireland are charged for water when their use exceeds an annual allowance, set by the CRU. Average domestic users, who do not exceed this allowance, do not pay a direct tariff. As such, opportunities for pricing strategies such as differential tariffs or rebates may not be feasible, but subsidies for technologies are potentially an option. Non-monetary incentives such as the use of technology, regulatory drivers and awareness campaigns will be paramount to incentivising water conservation. Both the academic literature and policy reports have argued for non-price conservation tools to support water pricing (Renwick and Archibald 1998; Dige et al., 2017). In many cases where conservation plans successfully reduced water demand (e.g. Renwick and Archibald 1998; Kenney et al. 2008) the success was achieved by multiple price and non-price interventions working in combination.

Renwick and Archibald's model (1998) suggests that household water consumption is affected by a variety of characteristics which can be broadly grouped under four themes:

- Pricing and Regulation
- Household Characteristics
- Water-Using Appliances, and
- Situational Factors

Effective domestic water conservation is likely to be context-specific and require local information, because consumption is driven not only by household characteristics, and the presence and prevalence of price-based strategies and/or restrictions, but situational factors, such as the location of the house and the rainfall it receives, may also influence the amount of water consumed (Jorgensen, 2009). This suggests that the timing and context of the implementation of non-pricing strategies may also affect their likely success. Perhaps unsurprisingly, countries which are water scarce, such as Australia or South Africa, have had success in implementing non-price based strategies. The increased frequency in recent years of water restrictions and conservation orders in Ireland (Rolston, 2020) suggests that it could now be a pivotal time to engage with water conservation. It may also mean that water consumers are more likely to understand the need to adopt changes. The following sections explore potential strategies for incentivising water conservation in Ireland, acknowledging the challenges and opportunities for their implementation.

4.1. Price-based strategies

Twelve years after the Water Framework Directive was implemented (in 2000), the Blueprint to Safeguard European Waters sought to direct focus towards water efficiency measures following concerning trends on the increase of water scarcity and stress within Europe (European Commission, 2012). This Blueprint sought to identify options to integrate water-efficiency priorities into policy and address the climate change challenge, through two key actions:

- the development of water-efficient technologies; and
- the implementation of water pricing policies that provide an incentive to use water efficiently, coupled with the wide-spread installation of metering devices (Dige et al., 2017)

Pricing mechanisms, and the metering strategy that often underpins them, are thought to raise awareness with consumers whilst simultaneously stimulating innovation in the market for efficient technologies (Dige et al., 2017; European Commission, 2012). However, the evidence of the success of pricing and non-pricing measures to manage water demand in Europe is somewhat lacking (Dige et al., 2017).

There are a range of price-based mechanisms available to incentivise the conservation of water in the domestic sector including tariffs, charges or fees, and taxes or subsidies (Lago et al., 2015). A *tariff* is defined as a 'price to be paid for a given quantity of water or sanitation service'; whereas a *tax* is a 'compulsory payment to the relevant authority for a behaviour that leads to the degradation of the water environment'. A *charge (or fee)* is 'a compulsory payment to the competent body (regulator) for a service directly or indirectly associated with the degradation of the water environment]. Finally a *subsidy* is 'a payment from government bodies to producers' with the aim of either (i) influencing levels of production, prices or other factors, or (ii) encouraging the adoption of specific practices (Lago et al., 2015).

These may be implemented through the following pricing mechanisms (Lago et al., 2015):

- *Volumetric water pricing* – as an incentive to the customer to use less water.
- *Charge/fee on abstraction licenses* – to disincentivise abstraction.
- *Subsidies for water saving technologies* – to encourage uptake of efficient devices.
- *Tax breaks for utilities*– to incentivise network efficiency and minimise leakage.
- *Subsidies/ lower tariffs for water re-use*– to encourage the use of alternative water sources such as grey water.

Given the focus of this report is on domestic use, volumetric tariffs and subsidies for technologies are the only pricing mechanisms discussed. Volumetric water pricing, based on water-use metering, is the most commonly implemented pricing strategy (Dige et al., 2017). Water tariffs can take one of several forms including a fixed water tariff, where the price is unrelated to the quantity of water consumed; a uniform volumetric tariff, where a fixed amount is paid for each cubic meter of water consumed; or a block tariff, where the volumetric rate increases or decreases with the amount of consumption (Dige et al., 2017). In a survey of 558 cities, across 184 countries, Ireland and Northern Ireland were the only places that did not directly charge a tariff for water (GWI, 2019). Whilst the notion of putting a price on water is, in theory, straightforward, it is often difficult to implement (Lu et al., 2017). The average price of water for domestic use in Europe is highly variable, ranging from €9.32/m^3 in Denmark to less than €2 in Greece, Spain and Portugal (Smart Water Magazine, 2021) (Figure 39). In general, there is a trend towards higher water costs in the more northerly parts of Europe (Figure 34). However, whilst water tariffs vary substantially between countries (Figure 34), there can often also be large variations in the amount charged to households within the same country, typically due to factors such as geographical location and population density (Dige et al., 2017).

The affordability of water bills (relative to household income) can vary substantially from country to country (Figure 39). Denmark has the highest average water price in Europe but water consumption in the city of Copenhagen is less than 100 litres/person/day (IWA, n.d.) The total water tariff in Copenhagen in 2017 was €5.17/m^3, set annually by the city government. The tariff consists of drinking water supply (€1.12/m^3), discharge of wastewater (€2.18/ m^3), green taxes (€0.79/ m^3, to account for energy consumption (CO_2-tax), discharge of polluting compounds and limited natural resources (i.e. tax for water loss and discharge of nitrogen and phosphorous)), VAT (€1.03/ m^3) and a national water resource tax (€0.05 m^3).The price-based strategies were supported by substantial non-price based mechanisms (including support for the establishment of water-saving toilets, a two-year awareness campaign, mandatory water metering, and extensive rainwater and greywater reuse to limit potable demand) (IWA, n.d.) Conversely, in countries (such as Spain or Bulgaria) where water bills are generally relatively small in comparison to household income, price-based measures are not an effective deterrent of wasteful use (Clark & Finlay, 2008, Lu et al., 2017; Tortajada et al., 2019). In these instances, price-based strategies alone may be insufficient, but could still drive change when used in combination with non-pricing strategies or behavioural interventions (Lu et al., 2017).

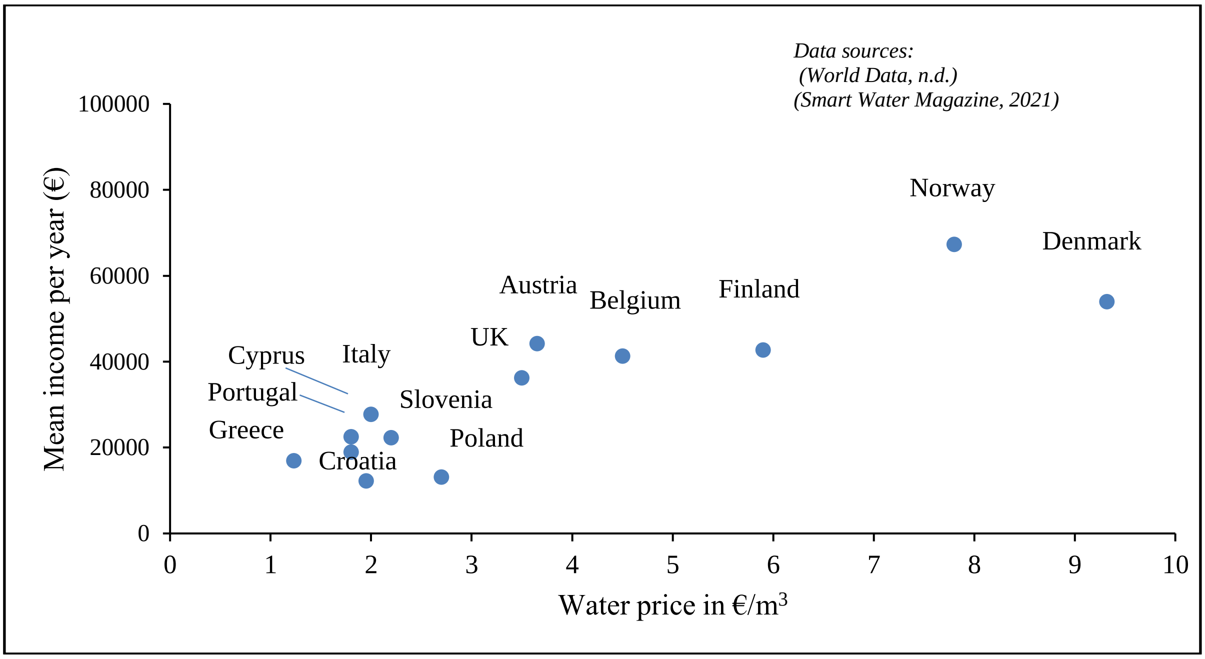

Figure 39 Average water price in Euros per cubic metre (€/m^3) relative to mean household income in Europe.

Metering is essential for effective water pricing mechanisms, but the move towards quantifying volumetric water use has a cost associated with it (i.e. to install and use meters (Cominola et al., 2015; Zetland, 2016). Under Danish legislation, all properties connected to the public supply must have water meters installed at property level (IWA, n.d.). However, multi-occupancy dwellings such as apartments are only required to install one water meter at property level (IWA, n.d.). There is a fee for having a water meter, but housing associations in city of Copenhagen have obtained water savings up to 20% when establishing individual water meters (IWA, n.d.). Furthermore, in England, the average cost (to the water company) of installing meters is estimated to be £220, although this varies depending on whether the meter is installed internally (£106 to £385) or externally with a new boundary box (£293 to £471) (Walker, 2009). But there is evidence to suggest that the installation of meters delivers benefits beyond being able to quantify, and therefore charge for, water use. Metering also leads to greater awareness of water use by quantifying patterns and habits of use; identifying norm-based data and presenting options to achieve water savings (Lu et al., 2017). A study in the UK found that unmetered households use more water (40 litres/person/day more, or 25%) than metered households (Consumer Council for Water, 2021a))

Incentives for the uptake of water efficient devices can take the form of tax breaks on specific products, lower VAT, or subsidies (Dige et al., 2017). Subsidy schemes are far less common in the domestic sector compared to industrial and agricultural sectors (Dige et al., 2017). Other incentives may target alternative water sources or the use of grey water. For example, the Cypriot government previously provided subsidies for incentivising the use of groundwater of inferior quality and promoting the installation of grey water equipment for the flushing of toilets and watering house gardens (Dige et al., 2017).

A study by Water UK and Artesia in 2019 found that metering could lead to between 4 – 22 % reductions in per capita consumption depending on if the metering was progressive by region and voluntary (4 – 7 % PCC reduction) or fully and universally applied across England and Wales (12 – 22% PCC reduction)(Water UK, 2019b). Additionally, the report suggested that 'innovative tariffs' could reduce PCC by 2 – 6 litres/person/day (Water UK, 2019b).

4.2 Non-pricing strategies

There is often a cumulative effect with non-pricing strategies, in which the value of multiple interventions concurrently is considerably greater than the sum of its parts (Kenney et al., 2008). The following section covers targets, restrictions, alternative water sources, efficient devices and awareness campaigns. Targets are goal-oriented mechanisms to encourage water-users to reduce the amount they consume. Water restrictions seek to control the amount of water that can be consumed during periods of acute water shortage. Alternative water sources includes the use of rainwater harvesting and greywater recycling. Efficient devices are covered in section 1. Awareness campaigns are covered in section 5.

4.2.1. Targets

Two examples of target-based strategies are outlined below: Target 140 , from the Queensland Water Commission, Australia, which took place in 2007 and involved marketing campaigns to achieve the demand reduction; and Target 100, from Southern Water, England, which is ongoing (util 2040) and involves a combination of strategies including smart metering, water-saving technologies, education and rewards.

In Australia, the Queensland Water Commission (QWC) implemented interventions seeking to secure the water supply in response to an extremely severe drought. The primary focus was residential water use, which accounted for 70% of the total water use in the region (Walton and Hume, 2011). Interventions centred around an eight month campaign – **Target 140** – which sought to change the water use habits of residents and reduce water consumption from 180 litres/person/day to a target of 140 litres/person/day within one year (Walton and Hume, 2011). The campaign was successful: water consumption dropped beyond expectations to an average of 129 litres/person/day during the campaign. When water restrictions eased in 2009 (allowing up to 200 litres/person/day), residents typically continued to consume less than 140 litres/person/day.

The campaign faced several challenges at the outset due to:

- a lack of understanding around how critical the problem was – this was thought to be due to the parks in Brisbane remaining green despite severe drought in the wider catchment.
- a misunderstanding of who was primarily responsible for water consumption – with residents believing it was industry, and
- a lack of appreciation for the difference they could make as an individual (Walton and Hume, 2011)

The process of implementing the interventions involved establishing a target which was not only measurable and tangible, but also meaningful to individuals. Therefore, a reduction to a specified per capita consumption was selected. The target was deemed to be a ‘stretch’ as it represented a further 20% reduction than the level achieved through the existing water restriction approach (Walton and Hume, 2011).

Based on the market research, attitudinal marketing strategies were used to convince residents that water supply levels were critical, domestic use was primarily responsible for water demand, and small individual changes could be impactful (Walton and Hume, 2011). This was achieved through TV commercials, direct mail, print media, radio, online advertising and billboard. All forms of advertising incorporated these three key messages, in combination with the target 140 goal (Walton and Hume, 2011).

Feedback was a key part of the campaign, serving two purposes: (i) to provide information to households on how they were performing against the target and (ii) to congratulate residents on their efforts or encourage them to try harder. This was reinforced by mechanisms to create new social norms, including the adoption of the restrictions in non-residential locations along with endorsement by community leaders and local celebrities (Walton and Hume, 2011).

In the second example, Southern Water in England launched a demand reduction programme – **Target 100** – asking customers to reduce personal consumption to an average of 100 litres/person/day by 2040. Alongside this, the utility intends to reduce leakage within their network by 40% in the same time period. The strategy involves four key initiatives to achieving the target:

- the installation of approximately 100,000 smart meters to enable customers to track their own water use in real time,
- home visits to provide advice and water saving products and detect any leaks in the customers supply pipes and fittings,
- customer engagement to better understand how they currently use water and what might influence change, and
- a tailored incentive programme (Southern Water, 2021).

One such example of an incentive scheme was trialled in a community which had above-average use per person, in a region where abstraction licences had recently changed (Southern Water, 2021). The community was supported with education campaigns and home visits, and reduced its consumption by 8% resulting in a reward of free swimming lessons for all children in the local primary school (Southern Water, 2021).

4.2.2. Restrictions

Water restrictions reduce peak consumption during drought periods and can enable the transparent prioritisation of water use during shortages. However, whilst restrictions in times of acute water scarcity are generally considered to be effective in the short term, they typically do not result in behaviour change and therefore have little or no effect on water demand in the long term, if they are not accompanied by other measures (Dige et al., 2017).

For example, when there were severe water shortages in Cyprus in 2008 – 2009, periodic interruptions to domestic water supply were applied as an urgent water-saving measure (Polycarpou & Zachariadis, 2011). Whilst the measure mitigated the immediate problem of water shortage, it did not encourage citizens to change their consumption patterns and as such, had no impact on long term water demand (Polycarpou & Zachariadis, 2011). Similarly, following restrictions arising from a severe drought in 2007 – 2008 in Barcelona, only a very small reduction in water consumption (~ 5 %) was seen (Martin-Ortega and Markandya, 2009; Bernando et al. , 2015).

It may be interesting to evaluate the impact the recent restrictions in Ireland (including water conservation requests and night-time water restrictions in Donegal, Dublin, Laois, Kerry, Meath, Westmeath, Longford and Wexford in July 2021) had on water consumption. Given the lack of individual property metering, there is unlikely to be the granularity in the data of individual household consumption, but it may still be possible to assess levels of consumption before, during and after restrictions were in place, based on bulk flow meters.

4.2.2Alternative water sources

The use of alternative water sources involves a range of measures based on reducing demand for water from conventional sources (such as rivers, groundwater etc). Typically alternative sources refer to rainwater or reused greywater. Rainwater and greywater reuse provides a dual benefit in relieving stressors on water and wastewater infrastructure, by reducing non-potable demand for mains water and the volume of wastewater discharged to the sewer network. Rainwater harvesting primarily generates savings during wetter months, when rainfall is more abundant. Therefore, they may not provide a solution to meeting peak summer demand, unless larger rainwater harvesting systems are used, which are more reliably able to ensure supplies during drier spells. Conversely, greywater systems can provide water savings all year round, as they involve the reuse of used potable water within the house and are not affected by patterns of rainfall. The climate in Ireland is well suited to rainwater harvesting systems (Li et al., 2010), and incentivising the uptake of rainwater harvesting and greywater reuse could be an effective means for meeting future water conservation objectives. In the absence of a water tariff, there is a need for an alternative mechanism to incentivise the uptake and necessary maintenance of these systems in Irish households.

A report by Water UK and Artesia found that the widespread retrofitting of rainwater or greywater systems to existing housing stock could achieve PCC reductions of 8 – 39 litres/person/day (Water UK 2019b). In new build developments, savings of 24 – 36 litres/person/day could be achieved if community-level rainwater harvesting was implemented, collecting rainwater from roof runoff and in sustainable drainage systems within the development and treating it before supplying (in a separate system) for toilet flushing, outside use and potentially clothes washing (Water UK 2019b).

4.2.3. Efficient devices

The uptake **of a range** of non-pricing water demand measures – such as leakage reduction in water supply networks, and the installation of water saving devices and more efficient household appliances – has the potential to deliver significant reductions in water consumption from 150 litres/person/day to 80 litres/person/day (Dige et al., 2017; Lawson et al., 2018a). Water efficient devices can lead to a reduction in bills (if volumetric pricing is implemented) and also generate energy savings. However, there are costs associated with their implementation. Depending on the type of technology implemented (section 1.3 – 1.4) there may be (i) large upfront costs, and (ii) a complex and/or disruptive installation process (if these technologies need to be retrofit into an existing building). Therefore, for this strategy to be effective, the following barriers need to be addressed:

(1) the cost of purchasing and installing water-efficient technologies:
If price-based strategies are not implemented, and there is not a financial reward for saving water, there must be an alternative mechanism to facilitate the purchase and installation of such technologies.

(2) the market availability of such technologies in Ireland:
Without regulatory drivers, such as a mandatory water label or specific fittings standards, it is unlikely that the right products will be available (at the right price) for consumers to purchase. Additionally, information on how various products compare in terms of efficiency may not be accessible to customers, further limiting their capacity to choose an efficient fitting or fixture.

(*3) customer preference for higher consuming products*.
It is important to understand the experience a customer will have with a water-efficient technology. If the water-efficient product is not one that customers actually want, uptake will be limited. Amongst a growing trend of customers desiring higher performing shower systems, a retrofittable item such as a low-flow showerhead (that can readily be removed) must achieve a level of customer satisfaction in the performance (whether that's the spray pattern, velocity of spray etc) despite the reduced flow rate (Critchley and Phipps, 2007). Unless there are policy and regulatory drivers, economic incentives and effective awareness campaigns, the uptake of technologies is likely to be sub-optimal.

4.2.4 Awareness and campaigns.

Policymakers typically employ informational campaigns during short and disruptive crises, such as a drought or other supply interruption (Katz et al., 2016; Waterwise, 2013; Ofwat 2018). Informational campaigns typically create less public reluctance and can lead to a longer and deeper change in behavior than traditional policy instruments, such as economic or regulatory strategies (Katz et al., 2016). Comparatively, awareness campaigns can be deployed more readily and cheaply than other policy instruments (Katz et al., 2016). Campaigns can potentially have wide reaching impact, if a large proportion of the population is engaged and encouraged to change their behaviour. However, there are often challenges with monitoring the effectiveness of such campaigns. Campaigns are often introduced concurrently with other strategies. This is a logical approach and research suggests this increases the likelihood of achieving a desired behaviour change relative to a strategy involving a single type of policy instrument (Dietz et al., 2009). However, the simultaneous implementation of campaigns with other policies often limits the ability to determine how effective the campaign is (Katz et al., 2016).

A study in 2019 sought to evaluate a series of water efficiency measures implemented in five large areas (i.e. greater than 500,000 population) of Spain to reduce domestic water consumption between 2002 and 2016 (Tortajada et al., 2019). Previous studies exploring water conservation habits had shown that educational campaigns have a strong positive effect on Spanish households' decisions to purchase water-saving technologies and/or adopt water conservation habits (Martínez-Espiñeira and García-Valiñas, 2013). However, conservation habits are generally more well established when there is a focus on the link between water and energy consumption and efficiency (Martínez-Espiñeira and Nauges, 2004).

Tortajada's study sought to determine whether pricing or non-pricing measures were more effective for water saving purposes, and to identify, if possible, which non-pricing measures were most effective in delivering the lowest water use per capita (Tortajada et al., 2019). The analysis was based on questionnaires with utility managers. Whilst education and awareness campaigns scored particularly high in all cases, utilities' responses stressed that non-pricing measures were more effective than pricing measures to reduce the consumption of water per capita (Tortajada et al., 2019). This could be due to the low price of water in Spain (Figure 34) but the finding aligns with those obtained in previous studies in Germany (Schleich & Hillenbrand 2009) and across other cities in Europe (Stavenhagen et al., 2018). Other studies have noted that due to the (generally) low price of water, it is extremely difficult to produce water savings, by any mechanism, if there is not community will to change behaviour (Garrone et al.,2020).

Furthermore, a study by Water UK and Artesia suggested that behavioural interventions could result in savings of 1.4 – 6.9 litres/person/day (Water UK, 2019b). This study evaluated three types of behavioural intervention including a national, Government-coordinated programme of behaviour change; increased media and engagement with schools; and individual schemes and community incentives led by water utilities (Water UK, 2019b). The report did not differentiate between the savings that could be achieved through these different schemes, acknowledging that there is limited evidence on the effectiveness of behaviour change and there is therefore some uncertainty on the level of quantitative impact (Water UK, 2019b).

To develop effective awareness campaigns, leading to demand reductions, it is crucial to understand the factors that influence household water use. Unfortunately, many of the factors that potentially influence consumption – such as past water use history, exposure to restrictions, trust in water authorities, or knowledge of water saving behaviours,– are often not considered or recorded (Jorgensen, et al., 2009). In Corral-Verdugo et al.'s model, they noted that if people don't trust others to conserve water, they will use this to justify their own lack of motivation to conserve water (Corral-Verdugo *et al.,* 2002). Furthermore, if there is a lack of institutional trust in the water authority, people will be less inclined to cooperate with demand management programmes and save water (Jorgensen, 2009). Therefore it is critical that we understand factors which underpin and influence domestic water use, including demographics, household characteristics and composition, which can all directly impact on water consumption, by affecting conservation intentions, trust, attitudes, perceptions and habits (Figure 40).

Whilst the potential impact of education and awareness is high, it is highly dependent on delivery and situational context, such as location, seasonality, and/or who is conducting the campaign (Katz et al., 2016). It will inevitably be easier to engage water-users with conservation measures in countries that are water scarce, or in a way that addresses their needs. A key challenge for the success of water conservation interventions is addressing the systemic barriers in understanding about water. There is often a lack of awareness for the processes that underpin water treatment and supply, the amount of energy and resources that are required to produce drinking water, and the amount of water an individual uses.

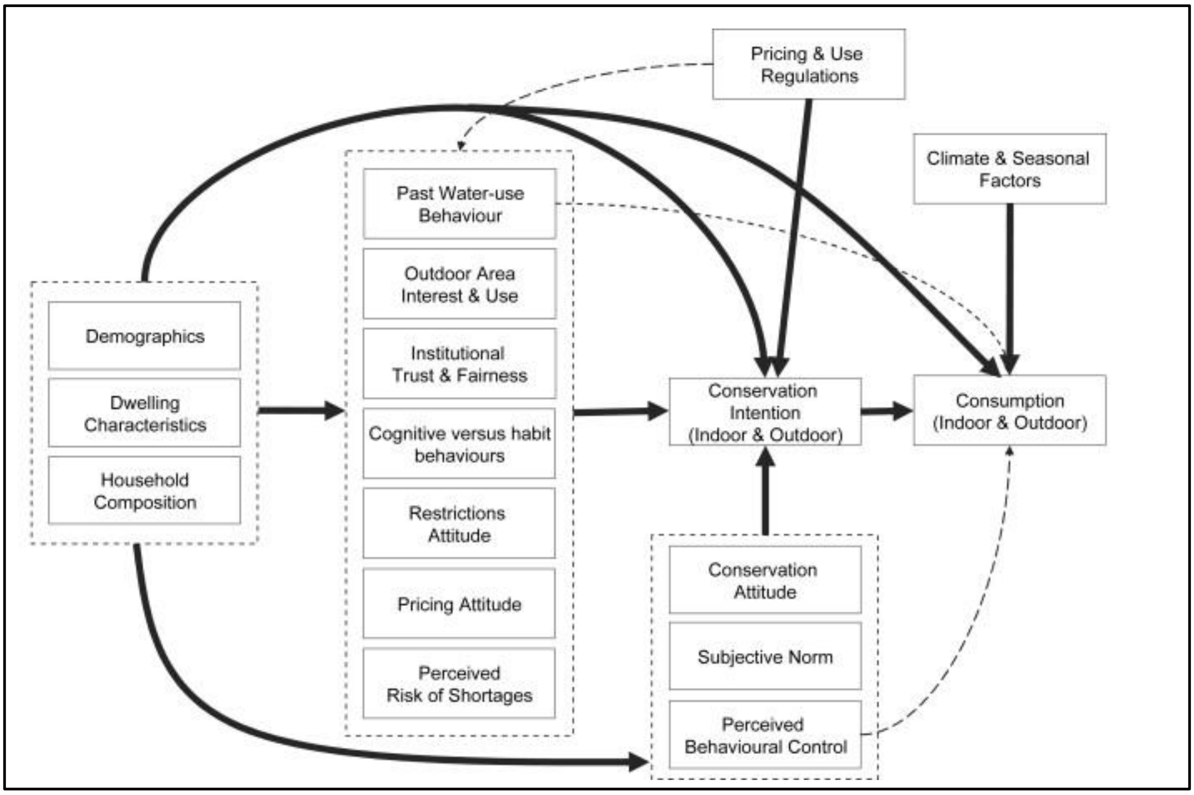

Figure 40 Integrated social and economic household water consumption model (Jorgensen, 2009).

5. Education and awareness

In the absence of water charges, water conservation policy relies upon public awareness, standards and legislation (McCarton & O'Hogain, 2005). A recent study found that 41% of people living in parts of England classified as "seriously water stressed" by the Environment Agency, think that water is plentiful where they live (Consumer Council for Water, 2021b). This highlights a systemic barrier in understanding and awareness about water resources, which is seen outside of England too. The growing pressure on Ireland's water and wastewater infrastructure (from population growth, climate change and changing water demand patterns) means that if action is not taken to reduce consumption, demand for water may outstrip available supplies in some areas, and in others, the amount of wastewater generated will exceed the capacity of the sewer network and/or wastewater treatment plants. Understanding and addressing attitudes to water use is key in driving behavioural change towards water conservation. Current and historic education and awareness campaigns from Ireland and other countries are appraised below.

5.1. Current and historic Irish Campaigns

5.1.1. Irish Water

Irish Water have made use of national and local media campaigns, targeted sectoral campaigns, An Taisce's Green-Schools programme, and the First Fix Free Scheme to promote domestic water conservation (Irish Water, 2021). The NWRP refers to the '*development of an online water conservation application'* to provide tips on saving water in the home (Irish Water, 2021, p. 124). Reference to water conservation on their website focuses primarily on sharing information with customers, including:

- how much water is typically used in the home
- where (and how) to save water in the home (Figure 41A)
- how to check for leaks, and
- other information relating to the processes that underpin water supply.

In addition to this, there are several resources for 'water education in Schools' including activity booklets, informational videos, and Scoilnet resources (Irish Water, 2019d) (Figure 41B). Irish Water has also been involved in An Taisce's Green-Schools programme for eight years, aiming to increase awareness of water conservation among primary and secondary school students (Irish Water, 2019d). This programme includes virtual water workshops, an annual poster and video competition, 'Water Ambassadors' and online teacher seminars, with a chance for each school to be named "Ireland's Water School of the Year" when they apply for the Green Flag. The theme in 2020/21 was "Valuing Water" (Irish Water, 2019d).

The impact of this programme has been quantified in the volume of water used: schools awarded the Green Flag in 2019/20 used, on average, one third less water, through increasing awareness, installing water displacement and water-saving devices and rainwater collection (Irish Water 2019c). Across Ireland, this equated to a saving of over 203 million litres of water in one year. However, the impact of the Green-Schools programme is wider than the savings achieved within the participating schools. Focusing education and awareness campaigns on schools draws on the concept of positive 'pester power'. Pester power as a term has moved from one with negative connotations of childrens' unrelenting requests for heavily marketed items, towards one describing childrens' capacity to modify the values and behaviours of their parents for the betterment of society and the environment (Furedi, 2009; Ritch, 2018). A study by O'Neill and Buckley (2018) suggested that Green-School children are positively affecting behaviours in the home. Half of all children surveyed confirmed they take responsibility for sustainable behaviours in the home – whether that's asking someone to recycle correctly or turn off the tap – and in doing they are not simply informing their parents, they are actively directing sustainable behaviour (O'Neill and Buckley (2018).

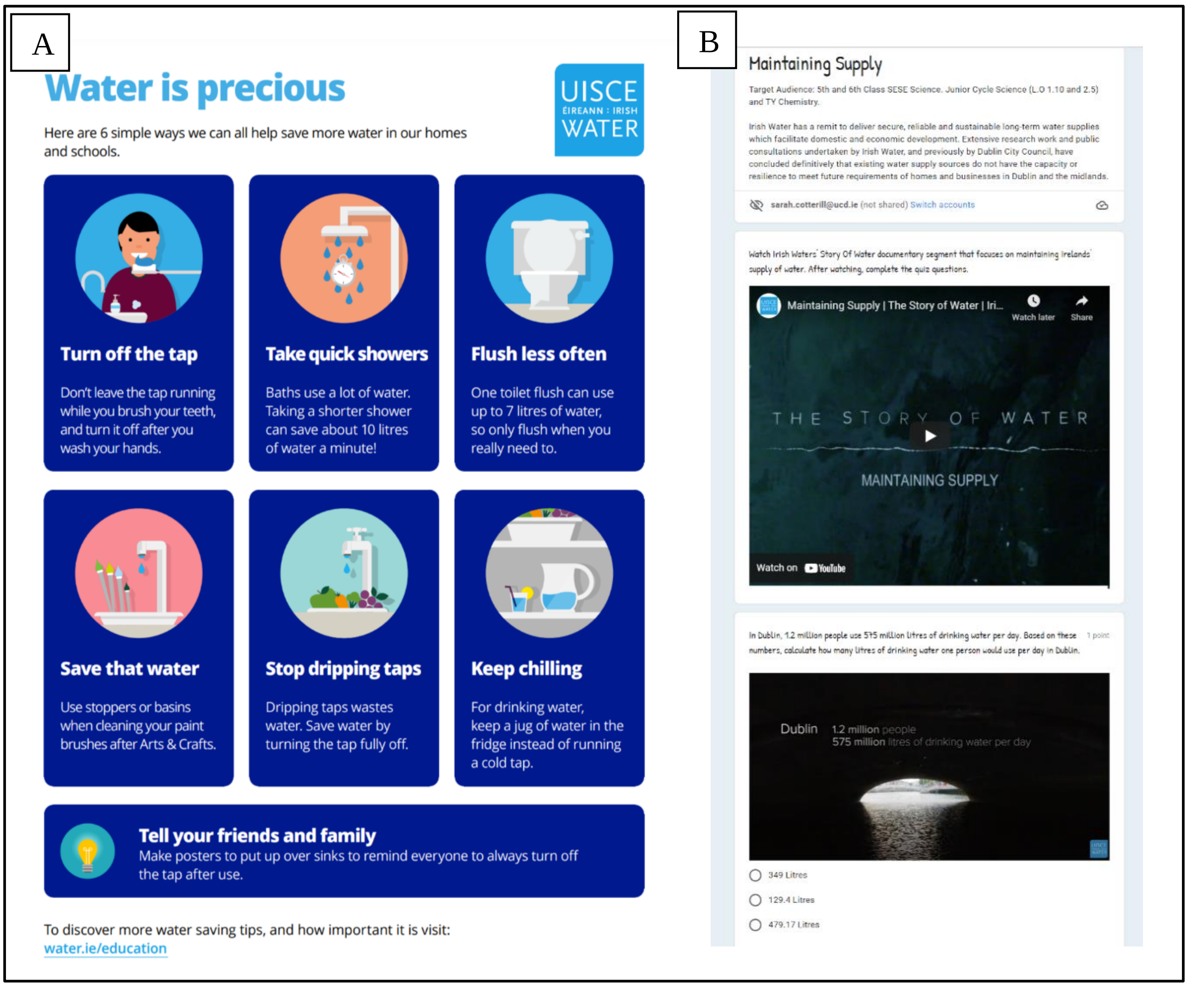

Figure 41 Examples of Irish Water's education campaigns include tips to save water (A) and Scoilnet resources (B)

5.1.2 National Federation of Group Water Schemes

Studies have shown that people are often poorly cognizant of their daily water use (Seelen et al., 2019; Hunt and Shahab, 2021). In a survey of 498 people across Europe, 80% underestimated their daily direct water use, and 86% underestimated their daily indirect water use, compared to the European average (Seelen et al., 2019). The level of education of the participants significantly influenced their estimate (with University alumni estimating higher use than those with a secondary-level of education), but gender and age did not (Seelen et al., 2019). In the UK, several cohorts of Masters students underestimated their water use by 76% compared to the average UK national range (Hunt and Shahab, 2021). The NFGWS launched a tool during 2020 Rural Water Week that allows householders to calculate how much water they use. The 'water saving calculator' (Figure 42) involves a series of questions, after which a personalised water report is generated, clarifying how much water is used and where the most significant savings could be achieved.

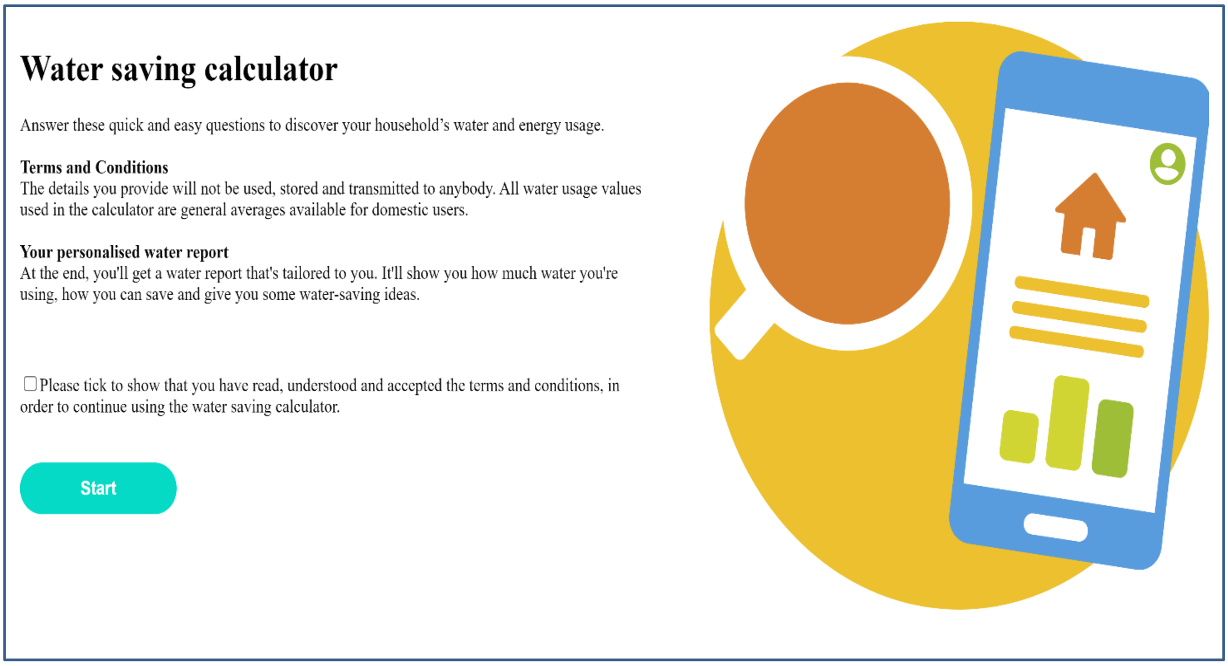

Figure 42 National Federation of Group Water Schemes Water Saving Calculator

5.1.3. Other schemes

The EPA Catchments Unit infographic (Figure 43A) highlights some of the benefits of using water saving devices and the resulting impact that could have on energy bills. Water savings from low-flow showerheads (12%), aerators (4 -10%) and toilet cistern displacement devices (9%) are presented, as well as the potential savings that could be realised from replacing a standard 9 litre toilet with a new dual (3/6 litre) flush toilet (16%) or upgrading to a water efficient washing machine (3%). The document suggests a potential maximum saving of €220/year for a typical 3-person household with an immersion heater, or €70/year for a 3-person household with a gas boiler.

An Fóram Uisce's educational objective is to collaborate with agencies and education providers to enhance the scale and diversity of water education programmes; facilitate networking and support resource sharing; initiate awareness campaigns that illuminate the value of water for personal, societal and economic well-being. Their "Water: Educational Resources and Inspirational Stories" booklet collates resources seeking to help people to understand and connect with their catchments, including their 'Water Matters at Home' video, An Taisce's Green Schools and Champions programmes, and Streamscapes' public engagement on conservation and 'voluntary stewardship' (Figure 43B).

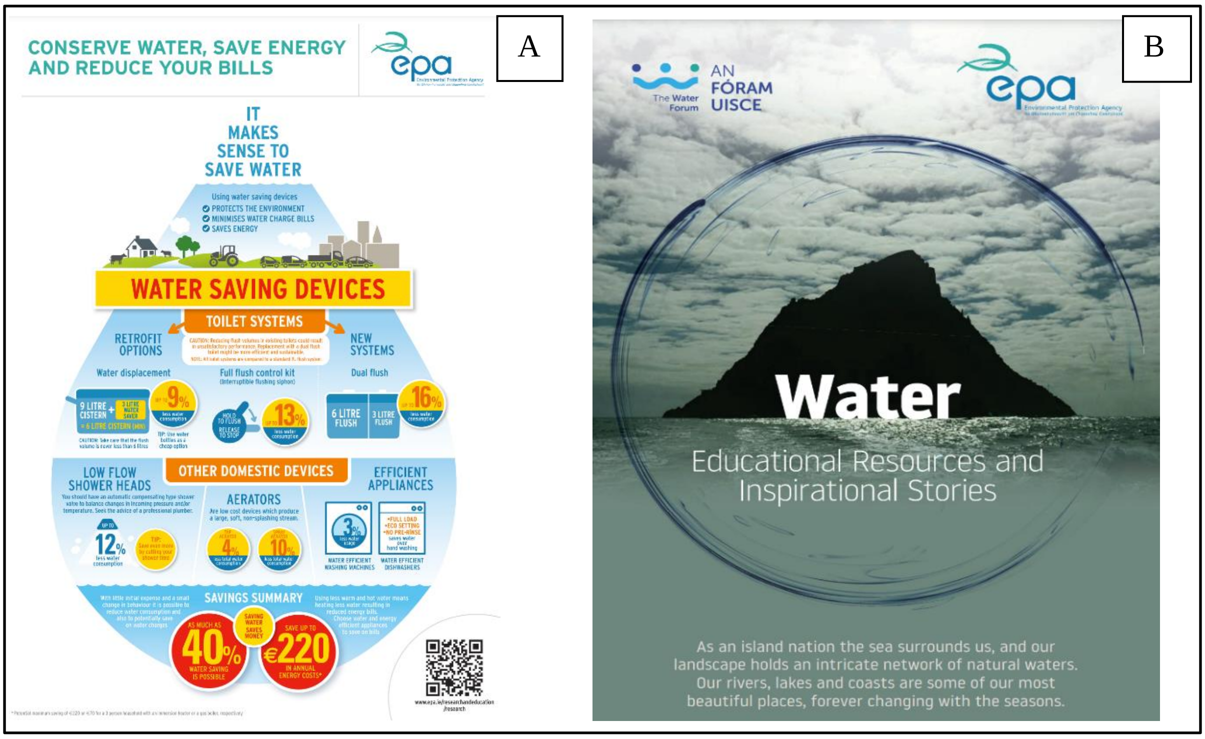

Figure 43 Awareness campaigns from Environmental Protection Agency & An Fóram Uisce

5.2. International examples

Singapore has implemented more than forty public education campaigns and policy initiative on the value and importance of water over several decades (Sanlath & Masila, 2020; Tortajada and Joshi 2013). These have included 'Water is Precious' in 1971 which led to a 4% reduction in consumption; the first annual 'Clean and Green Week' in 1990, which was one of the first examples of an engagement-based approach; or the 10% challenge in 2008 which made saving water a competitive activity (Tortajada and Joshi, 2013). In addition to this, working with the Ministry of Education, Singapore's PUB has introduced water conservation into the formal education system, including it in schools' curriculum (PUB, 2021). These educational strategies have been supported by data and monitoring and the use of smart technologies to provide real-time feedback on water use patterns (Sanlath & Masila, 2020). This is complemented by a "*shift towards creating a sense of community's stewardship in water management*"; encouraging communities to connect with water (Sanlath & Masila, 2020). PUB's campaign '*Water for All: Conserve, Value, Enjoy'* invited the '3Ps' (People, Public and Private) to share ownership and conserve water together (Tortajada and Joshi 2013). Whilst there are many good individual examples of campaigns and strategies, the key learnings from Singapore highlight the importance of;

(i) the combination of pricing and non-pricing strategies;
(ii) strong commitment and support from the government; and
(iii) acknowledging the full water cost in pricing, reflecting the value and scarcity of water (Sanlath & Masila, 2020).

It is important to note, that the adoption and implementation of international best practice is entirely context-dependent and may not translate directly from country to country.

A review of water efficiency initiatives used by UK water companies in 2015 revealed that utilities implement a combination of strategies (on average, more than six initiatives per company), including water audits, educational programmes, and the distribution of free of charge home water efficiency devices. In addition, eight of the 22 companies were noted to offer "*enhanced water efficiency programmes*" tailored specifically to their customers (Waterwise, 2015). Examples include "*Every Drop Counts*" (Northumbrian Water, 2019) – a scheme run by Northumbrian Water, involving a targeted community-based approach for a duration of 6 months of each year (Barrett, 2020). The scheme involves active engagement in the local community, clear explanation of the positive impacts of water-saving devices on the environment and customers' household water bills. The scheme has led to significant water savings at the community / town level as well as financial savings at the household level (Barrett, 2020). Other examples include Anglian Water's "Love Every Drop" (Figure 44) programme which seeks to encourage customers to save water in a region of England that receives the lowest rainfall (Anglian Water, 2019).

Figure 44 Anglian Water 'love every drop' awareness campaign infographic.

Other campaigns, not led by water companies include Waterwise's Pledge 2021, Water Makes it Possible, Water Saving Week, and Water's Worth Saving campaigns. Additionally, the (now closed) Water Efficiency (WATEF) Network led by the University of Bath and the Department for Food and Rural Affairs disseminated knowledge and information through a series of "champions", with subject expertise in water and energy, greywater recycling, water resilience and sustainable drainage systems (WATEF, 2013)

5.3 Evaluating campaign effectiveness

Education and awareness raising is often championed as one of the most effective and lasting ways of achieving behavior change towards water conservation (Sauri, 2013). However, there is little direct research on the impacts of campaigns on water conservation metrics (Water UK, 2019b), and even less still evaluating the effectiveness of such campaigns over time (Sauri, 2013). Educational campaigns – such as a poster or webpage with water saving tips – will typically create less of a public reaction, or meet as much resistance, and are generally cheaper and easier to deploy than other policy instruments (Katz et al., 2016). As such, they are a widely used policy tool for water conservation. However, little is known on whether this delivers a measurable impact in terms of direct water savings and/or attitude change. Furthermore, educational strategies are rarely implemented in isolation. Therefore, even if there was the intention to measure impact, it may be difficult to do in practice, in relation to the relative impacts of other policy instruments used (Katz et al., 2016). There is some evidence that social-marketing campaigns can be effective in changing behavior, especially for short periods of time and at a relatively low cost (Dietz et al., 2009, Saurí, 2013), however research in this area is reasonably scarce.

There is also a need for further investigation into whether people know how much they're using, what motivates them to save water, and who should be responsible for addressing these gaps in knowledge. A Water UK response to a consultation on PCC suggested that the main barriers to changing behaviour with regards to reducing personal water use included: (i) insufficient information about personal water usage; (ii) insufficient information about water scarcity and (iii) difficulty in changing habits (Water UK, 2019a). A survey by Waterwise (2017) supports this, noting that there "*appears to be a lack of communication regarding water efficiency with 62% (in 2015) and 67% (in 2016) of respondents reporting having had received no help, information or free water-saving devices in the past year. This is highest in Wales, where 85% report not having received it*." (Waterwise, 2017, p.15). A more public example of the lack of understanding about personal use can be taken from 2014, when cyclist Sir Chris Hoy and comedian Kevin Bridges appeared on a celebrity episode of "Who Wants To Be A Millionaire?". They won £20,000 for charity, after failing to correctly answer the £50,000 question which asked, "*according to the latest figures, how many litres of water does the average British household use in a year?*" with options of A: 1,000; B: 10,000, C: 100,000 and D: 1,000,000.

In a study into public attitudes to water efficiency in Wales, 44% of respondents stated that nothing would encourage them to use less water (Malet-Lambert, 2020). Only 3% noted they would be encouraged to use less water '*if bills increased / cost went up*', and 8% stated that they would use less water '*if bills went down or they were provided with incentives or discounts*' (Malet-Lambert, 2020). Metering was also mentioned as a mechanism to encourage water use with six percent of respondents suggesting this would encourage them to use less water. Some respondents referred directly to 'pester power' noting that their children had been taught about water efficiency in school and had encouraged them to be more cautious with their water use (Malet-Lambert, 2020). More than half of respondent (56%) stated they had made a conscious decision to use less water over the past few years (Malet-Lambert, 2020). The most common reason for doing so was that it "seemed like the right thing to do" (62% of responses) with only 14% and 16% stating that information received from water companies or elsewhere (respectively) had motivated them to use less water (Malet-Lambert, 2020). Almost a fifth of respondents commented that there's '*not enough support and advice on how to make changes'* and 11% of survey participants reflected that they don't feel it's a priority in their area as '*there's so much water in Wales*' (Malet-Lambert, 2020).

Findings from a Water UK response to a consultation on PCC (2019a) suggests that reducing personal water use requires a multi-stakeholder response not just in terms of taking policy actions but also in communicating the necessity for action to customers. This joined up approach may involve water companies, national and local government, regulatory bodies, and NGOs amongst other public and private organisations. For example, water companies may be best placed to communicate resilience aspects, whilst government would be better suited to demonstrating regulatory requirements (Water UK, 2019a). Whilst campaigns can be deployed more readily and cheaply than other policy instruments, barriers remain that can limit engagement with topics such as water conservation (Waterwise 2013). This could include public disinterest, a low public knowledge base, lack of resources for highly-effectual communications, and an over-reliance on strategies, such as social media (Waterwise, 2013, Ofwat 2018).

5.4. Strategies to facilitate behaviour change

Finally, there are a range of different strategies that can be used to promote water conservation behaviour, described by Koop et al., (2019) as behavioural influencing tactics (BITs). These BITs are based on three types of information processing: automatic, reflective and semi-reflective routes (Koop et al., 2019). This includes knowledge transfer, enhancing self-efficacy, the use of social norms, framing, tailoring, the use of emotional shortcuts, priming and nudging (Koop et al., 2019). Knowledge transfer involves "*providing information to raise awareness, change attitudes and behaviour*" (Koop et al., 2019), as exemplified by educational posters or webpages (e.g. Figure 41 or Figure 44). However, there may be questions over how effective these one-sided messages are, and if they're only meaningful if (and when) people know how to change their behaviour and if this is feasible to them (i.e. affordable, easy to implement etc). A collaborative effort on knowledge transfer, with all agencies and partners responsible for water, may be the best approach. Enhancing self-efficacy involves, "*providing tips, advice and concrete examples about how people can save water and enhance their water conservation behaviour*" (Koop et al., 2019). This could arguably be delivered through the use of posters / informational campaigns as with knowledge transfer, but may be more effective during water audits and home visits (see examples from UK Water Companies in 5.2. International examples).

Social norms are "*behavioural patterns that are semi-consciously applied to conform to social environments. Experiments indicate that normative messages are effective*" (Koop et al., 2019). This might include competitions amongst community groups / peers to rank water conservation achievements (e.g. Singapore's 10% challenge, see 5.2. International examples) or through the long-term repetition of messages until they become accepted as the 'norm'. Framing involves "*selecting and emphasising certain aspects to achieve a desired interpretation by using unconscious biases in information processing*" (Koop et al., 2019). When messages are framed as suggestive, or designed to appeal to intrinsic motivation they are generally more persuasive. Framing the role that water conservation may be able to play in contributing to the climate crisis, through the reduction of greenhouse gas emissions with reduced water use, or in meeting the needs of future population growth and housing development, may be more likely to incentivise the motivation to change. An example of this being implemented as a strategy internationally includes the Target 140 scheme (see 4.2.1. Targets) in Australia linking with a drought in Queensland.

Tailoring involves the use of "*data driven, personalised messages that increase recipients' responsiveness"* (Koop *et al.*, 2019). This relies heavily on the use of real-time information, through smart meters and devices (e.g. Figure 11) to prompt immediate (and often temporary) water savings. It is not known whether these short term savings translate into longer-term conservation habits. Tailoring may be more effective if reinforced through repetition, social norms and framing. The use of emotional shortcuts seeks to "*evoke emotions to influence people's response to (unrelated) messages*." There is a balance to be had in terms of inducing positive emotions, which may encourage cooperation and trust or making use of humour which can reduce levels of resistance, and negative emotions, such as fear or concern, to drive action in response to that fear (Koop et al., 2019). The latter is best applied with groups that feel high levels of self-efficacy (Koop et al., 2019). Emotional shortcuts can provide benefits for a water-related topic indirectly, through engagement or interest with a separate topic. A good example of this is the '*Let it Bee'* campaign (Corrigan, 2020) by the National Federation of Group Water Schemes which, through focusing on the danger of pesticides to honey bees and biodiversity, delivered benefits towards the protection of drinking water sources and water quality. Understanding how to make water conservation most tangible and relevant to the public is a key next step.

Priming is when, "*the exposure to one stimulus – such as words or a smell – influences a response to a subsequent stimulus*" (Koop et al., 2019). It involves unconsciously processed cues, or primes, which can lead to behaviour change. It is largely an unexplored area for domestic water conservation (Koop et al., 2019). Finally, nudging, *"…alters people's behaviour in a predictable way without forbidding or limiting freedom of choice. The principle is to make the 'better' option more convenient to select*" (Koop et al., 2019). Nudges are rarely applied to water conservation, although water labelling could be potentially considering under this influencing tactic. In Singapore, sales of higher ranked (3-tick) washing machines increased after the water labelling rating system was introduced, indicating the potential for nudging customers towards more efficient technologies.

Summary and Outlook

Water is a valuable resource, but it is not truly valued. Most people do not know how much they use, or why it is detrimental to use more than is necessary. But water conservation can have societal, environmental and economic benefits. Saving water saves energy: both by reducing the amount of water that has to be abstracted, treated and pumped, and by reducing the amount that is heated in the home. This saving can be seen by the customer, in the financial saving on their energy bill, and the environment, through the reduction in greenhouse gas emissions. Furthermore, using less water can lead to a reduction in the volume of wastewater generated, helping to reduce pressures on the capacity of the sewer network and wastewater treatment plants, thereby reducing the likelihood of any detrimental impact to the environment associated with exceeding capacity.

However, water conservation can be seen as a 'wicked' problem, whereby even the most innovative technical solution may not deliver the intended impact. Long-term reductions in water use are likely to require a combination of strategies, drawing on regulation, behaviour change and smart technologies. Savings arising from non-price based mechanisms, particularly where behaviour change is evident, may last longer than those induced by price-based measures. Understanding the behavioural factors that underpin attitudes towards water conservation and how readily these may be influenced will be key. The factors underlying the opposition to domestic water charges in Ireland were multiple and complex and any future attempts to address them may be challenging. Instead, efforts may be better invested in 're-framing' the purpose and objectives of water conservation, with unified consistent messaging.

As such, there is a clear need for strong leadership from all agencies responsible for water – including utilities, government, regulators, supply chains, innovators and the general public – to work in a joined-up manner on the sustainable stewardship of water. This may involve:

- the implementation of bolder regulation and policy, introducing per capita consumption targets, mandatory water labelling and revised building regulations and fittings standards,
- the introduction of smart metering (made available free to every household) to raise awareness on where and how water is being used,
- the delivery of effective awareness campaigns which articulate why (and how) behaviour change on water use is necessary,
- addressing systemic barriers in understanding about water supply, treatment and availability,
- further research into customer acceptance of water-efficient technologies, factors influencing consumer choice of products, and cost-benefit analysis of implementing non-pricing strategies such as awareness campaigns to deliver behaviour change.

Knowledge and feedback on actual water use is key to changing water consumption behaviour. Smart metering is the best mechanism for achieving this. Where metering is not present, alternative mechanisms will be required to ensure consumers are aware of their water use relative not only to their previous use, but to other contextual factors. The frequency with which householders incorrectly estimate their water use demonstrates firstly that this knowledge is currently lacking, and secondly that there cannot be exclusive reliance on individual attitudes and beliefs to reduce water consumption. Whilst mandatory measures are likely to be more reliable in reducing residential demand, a combination of regulation, water-saving technologies and behaviour change is likely to result in the best outcomes.

Finally, for long-term and effective changes to water conservation policy, it is recommended that they are system-wide; underpinned by regulation; data-informed; and adequately resourced. System-wide refers both to the policy itself and the team of stakeholders delivering such policy. To deliver a long-lasting system-wide policy for water conservation, a combination of mandatory regulations, voluntary incentives and access to the best-available data will likely be required (Robins et al., 2017). These regulatory, educational and technological interventions should be financed appropriately and back up by effective systems of monitoring and evaluation. Finally, providing the best-available information, or the most efficient technology, will likely not be enough. Stakeholders – whether agencies and partners, or the general public – need to better understand and engage with how water resources are managed, through active participation and collaboration (Robins et al. 2017). There are extensive networks of agencies who have strong connections with water in Ireland, but these networks needs to be mobilised and aligned to deliver the greatest impact.

Acronyms

BER – Building Energy Rating
BREEAM – Building Research Establishment Environmental Assessment Method
CRU – Commission for Regulation of Utilities
EPA – Environmental Protection Agency
GDA – Greater Dublin Area
IoT – Internet of Things
LEED – Leadership in Energy and Environmental Design
NFGWS – National Federation of Group Water Schemes
NSAI – National Standards Authority of Ireland
PCC – Per Capita Consumption
PHC – Per Household Consumption
RBMP – River Basin Management Plan
RWH – Rainwater Harvesting
SAWM – Smart Approved WaterMark
WFD – Water Framework Directive
SuDS – Sustainable Drainage System
ULFT – Ultra Low Flush Toilet
WC – Water Closet
WCO – Water Conservation Order
WELS – Water Efficiency Labelling and Standards
WRZ – Water Resource Zone
WTP – Water Treatment Plant

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