# Water behaviour modelling for efficient ICT-based water management in urban environments: A United Kingdom case study.

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A thesis submitted in partial fulfilment of the requirements of Cardiff University

for the degree of Doctor of Philosophy

School of Engineering

- 2018 -

# Acknowledgements

I would first like to thank my two supervisors. Dr Thomas Beach for his incredible help, advice and support over the course of this PhD. I am very grateful and lucky to have had such an understanding supervisor, always there to answer my questions and help me progress. Un immense merci au Prof Yacine Rezgui: Thank you for giving me the opportunity to pursue these four years of research in the first place. I didn't expect it but the more I learnt and researched about my subject, the more interested and passionate I became. This gave me a new perspective on my future career and I am really happy to have started this project with your help.

I would also like to acknowledge the partners involved in the WISDOM project, who made part of this research feasible. I am glad to have been involved and to have contributed to this project.

A big 'thank you' to Dr Dimitrios Xenias, for our coffees at Costa and the hours spent discussing statistics (among other subjects). I am so grateful for your help on this: merci! The next 100 cappuccinos are on me!

Thank you to Dr Isabelle Durance and to the Water Research Institute team who supported me and gave me the time and resources necessary to finish my PhD. I couldn't have hoped for a better way to end these four years of research. It is a pleasure to work with you all and I learn a lot every day.

Merci à toute ma famille et mes ami(e)s en France qui ont toujours été présents et qui m'ont soutenu à distance (et qui vont maintenant devoir lire ma thèse).

Last but not least, thank you to the incredible friends that I met over the course of my PhD, those that stayed in Cardiff and those that left, from the first year to the last one. I am really lucky to have shared this with you all. These four years turned into an amazing life experience that I will never forget. Cardiff is now filled with memories of good times spent together and I am really grateful for that

# Abstract

The global water crisis, caused by ever-increasing population growth, climate change and growing urbanization, requires a sustainable use of water resources worldwide. In the United Kingdom (UK), despite heavy rainfall and common prejudices, population growth and aging water infrastructure engender significant periods of drought and flooding. While increasing the water supply is a solution to current problems, reducing demand by promoting behaviour change, appears as an environmentally and economically interesting approach to better manage water resources. To that end, the rapid development of Information and Communication Technologies (ICT) offers an opportunity to deploy both structural and voluntary strategies to reduce demand. While a growing body of literature recognises their efficiency in water-scarce countries, there is a lack of research regarding the use of ICT to promote behaviour change and water savings in water-stressed countries such as the UK.

Using surveys and case studies, this research project demonstrates that the water-saving user interface designed in the context of this project is an efficient tool to increase users' awareness of their water usage, improve their knowledge of environmental issues and ease the performance of water-saving actions in households. Providing individuals with an overview of their households' water consumption through this interface is also identified as the most efficient method to encourage domestic water savings.

By designing and testing an innovative water-saving interface based on behaviour change theories, recommendations from previous studies and results from initial surveys, this research project contributes to existing knowledge and provides a new understanding of the impact of ICT and behaviour change methods on the promotion of water conservation in British households. The author believes that this research project can be used to inform British water companies' strategies and increase the efficiency of their conservation campaigns. By highlighting the need for large-scale structural changes to facilitate domestic water savings, this project also suggests recommendations to increase the impact of future governmental initiatives regarding domestic water conservation.

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# Chapter 1: Introduction

## 1.1 Context of the Study

This section gives an overview of current water challenges affecting countries worldwide in Section 1.1.1. It then focuses on the situation in the UK in Section 1.1.2 by describing the current stress on British water resources, the management of water issues in this country and the levels of households' water consumption. Section 1.1.3 then reviews a range of solutions to tackle water issues and explains how behaviour change, coupled with the use of ICT, can reduce the water demand in the UK.

### 1.1.1. Stress on Water Resources Worldwide

Growing water demand, caused by ever-increasing population growth, climate change and urbanization is one of the most important environmental problems facing the water industry, alongside the contamination of water sources [2], [3]. A large part of the World's population is currently experiencing water scarcity [4] and, by 2030, half of the people living on earth will rely on stressed water resources [5], [6]. While most of these people live in the World's poorest countries, wealthier nations are also facing this water crisis. In developing countries, the first necessity is to provide clean water to individuals whereas in developed countries, the current crisis makes it crucial to better manage water to avoid shortages of water supply [7].

Climate change, a key factor effecting water scarcity, does not result only from natural causes and human influence on global climate is real [3], [8]. The actual standards of water consumption have an important effect on water resources [3]. According to the United-Nations, the minimum amount of water required to sustain basic human needs is 50 litres per person per day. However, there are currently important discrepancies in the daily amount of water used per person around the world [9]. While some developed countries exceed this basic amount of water. i.e. 575 litres per person per day in the USA, the poorest countries are significantly under this threshold, i.e. 20 litres in Ghana [9], [10]. Social and environmental balance based on a solidary and equitable use of water is therefore crucial to face the current global crisis [11]. Sustainable use of water resources needs to be encouraged [12]. Sustainability is defined as the "pattern of use which ensures satisfaction of needs for both the present and future generations"[12]. This implies that current water resources have to be consumed within the limits of their natural regeneration and unnecessary use needs to be avoided [11], [12].

International action to resolve worldwide water-related issues is traditionally carried out in the form of negotiations and agreements [13]. However, governments are not always ready to confront the issue of unsustainable consumption and there is often a lack of commitment when it comes to implementing these agreements [13]–[16]. This is particularly true in developed countries where individuals are encouraged to consume to revitalise the economy instead of being urged to act sustainably to help the environment [14], [17]. Nevertheless, the United Nations is currently taking initiatives to mitigate the effect of climate change and to encourage sustainable consumption through the seventeen Sustainable Development goals, part of the 2030 Agenda for Sustainable Development [18], [19]. Among others, these goals aim at increasing water-use efficiency and at raising awareness and educating individuals about climate change [18]. While this agreement is not legally binding, each country is asked to develop a national framework to achieve these goals [19]. The European Water Framework Directive however provides a legal framework for the preservation of the quality and quantity of fresh water to foster "the emergence of a water-saving culture in Europe" [20]. In the UK where water stress is becoming a growing concern, water resources are therefore protected by national regulations, as described in the following section [21]–[24]

### 1.1.2. Water in the UK

This section reviews the current situation in the UK, from the state and management of water resources to the levels of households' water consumption and domestic trends of water usage.

#### 1.1.2.1. The State of Water Resources in the UK

Despite being internationally known for its heavy rainfall, the UK has been facing droughts since the 1890s [25]. In addition, water demand is growing particularly fast in urban areas and the UK population is expected to reach 71.6 million inhabitants by 2033 [26]–[28]. This growth in population increases the risk of water shortages in regions where demand for water is high but where resource availability is already low [29]. As an example, the South East of England is now classified as a water-stressed area due to droughts and a constant increase of water demand [30]–[32]. In addition, the UK water infrastructure was constructed in the nineteenth and early twentieth century needs to be maintained or replaced, requiring important investment as it increases the risk of water contamination and leakage [33], [34]. The vulnerability of the UK water infrastructure became apparent during the 2007 flooding which resulted in loss of water supplies in Gloucestershire, Worcestershire, and East Yorkshire and in power failures that affected thousands of people [27]. Other consequences of this flooding ranged from bank-slipping incidents, flooding on the rail networks and damages to electricity distribution [27].

#### 1.1.2.2. The Management of Water Resources in the UK and the Introduction of Structural Changes

The undeniable stress on UK water resources caused by population growth and climate change therefore requires an improvement in the management of national water resources [30]. The need for improved water management is translated in the 2003 Water act stating that "the relevant authority must, where appropriate, take steps to encourage the conservation of water"[21]. Regulating bodies including the Environmental Agency and the Water Services Regulation Authorities (Ofwat) whose duty is to contribute to "the achievement of sustainable development", set different voluntary targets for water companies to reach, enforce orders and take action against any company that does not meet its targets [22]. It is a statutory requirement for each water company to produce water resources management plans every five years explaining how they are dealing with managing "the needs of future populations" and dealing "with climate change" [23], [24]. In addition, Waterwise, is also in charge of encouraging water efficiency within the UK water industry [35]. With the UK Government's water strategy currently aiming at reducing daily water consumption per capita to 130 litres a day by 2030, water companies must aim at reducing the amount of water delivered and encourage customers "to use water wisely" [24], [36].

Yet, the absence of subsidies from the government have resulted in a slow development of water conservation measures compared to many developed countries [37], [38]. For instance, delivering feedback on water consumption is currently proposed by some governments as an extension to the implementation of smart meters to counter the growing water demand and consumption [39]. However, while the implementation of energy smart meters is ongoing in the UK, the UK lags behind on that matter as only 40% of houses in Wales and England have a traditional water meters installed [40]–[42]. Conventional water meters are being installed in all new properties and on consumers' request [28]. However, it is considered that "there is currently no economic case for a blanket policy for smart or conventional water metering because the benefits of metering vary across the UK" [28], [41], [43]. Only water companies in water-stressed areas, such as South-East or Eastern England, can ask the Government for permission to launch compulsory metering programmes [25], [28], [40].

The implementation of pricing policies to regulate water usage, such as volumetric charging, is also limited in the UK [44]. Water prices are set and controlled by an appointed regulator, Ofwat, under the 1991 Water Industry Act, which makes the introduction of new prices difficult in England and Wales [44], [45]. Additionally, the necessity to consider low-income households challenges the adoption of such measures [44]. The high and growing levels of water debt in the

UK show that some people cannot afford to pay for water in the present context and might be highly affected by the enforcement of new charges [44], [46]. The government therefore stresses that water bills should remain fair and affordable [24]. As a result, in England and Wales, the average household water and sewerage bill for the year 2016-17 was just over £1 per day [47]. According to [44], "at the points of use, water is completely free to [UK households]". This low cost does not encourage individuals to avoid waste, excessive usage or to be more careful about their water consumption [44].

On a practical level, water consumption patterns in the UK challenge the implementation of pricing measures. Adaptive water pricing measures that are successful in the USA and Australia might not have a similar impact in the UK [48]–[54]. Indeed, the large amount of daily water consumption per capita in these countries creates more feasible opportunities for water savings in those countries. For instance, in Australia, residential outdoor water use amounts to 29% of households' overall water consumption whereas, in the UK, outdoor water consumption represents 7% of the average household water usage [55]–[59]. Due to these different levels of water consumption, opportunities to save water in the UK are more limited and domestic consumption might not be responsive to the implementation of different water prices [53], [60], [61]. Moreover, the efficiency of pricing policies is limited when people are unaware of the amount of water they use [62], [63]. The deployment of meters on a large-scale to inform individuals of their consumption is therefore required. Yet, this is contradictory with the current lack of compulsory metering in the UK [41], [44].

#### 1.1.2.3. Water Consumption in the UK

Domestic water consumption in the UK mainly consists of activities such as "bathing and showering (33%); toilet flushing (30%); washing machines (13%) and dishwashers (8%) [59]. Water is also used for cooking and drinking purposes. Water usage is often the result of performing different types of practices and does not come from a first intention to solely use water [29]. Thus, domestic water consumption is linked to other habitual practices, and becomes invisible for individuals [29]. Moreover, discretionary activities or non-essential activities linked to leisure purposes are becoming more important [64]. Water usage is often exceeding what is normally required or what is considered reasonable for basic purposes [64]. Social and cultural changes cause households' water demand to increase [65], [66]. For example, having clean clothes and constantly preventing body odours are now socially and culturally required [65]. Similarly, showers are not only used for sanitation needs anymore but also as a way to relax [64].

Water consuming activities at work are also an important part of a person's daily water consumption. They indeed represent a third of an individual's daily water usage [59]. Out of the

150 litres of water used daily per person in the UK, an employee uses approximately 50 litres at work in this country [59], [67]. However, water is used differently in households and in non-domestic premises. In businesses and offices, water consumption generally results from activities such as toilet flushing (63% of the building's water consumption), washing (27%), canteen (9%) and cleaning (1%) [67].

### 1.1.3. Finding Adequate Solutions to the Stress on Water Resources in the UK

A better management of water resources in the UK is crucial to address current water issues. Solutions include increasing the water supply or reducing the water demand. It is argued in this section that reducing demand offers various advantages. As suggested by the literature, this can be done through the promotion of behaviour change using ICT.

#### 1.1.3.1. Increasing the Water Supply

Issues regarding the current state of the water system need to be addressed both by considering supply and demand options [28]. Concerning water supply, it is first important for water suppliers to exercise control over the abstraction process in order to avoid damaging the environment by abstracting an excessive amount of water. The consequences of over-abstraction can be severe, ranging from the sinking of water tables to the intrusion of saltwater into groundwater [68]. Abstraction is therefore regulated by entitlements, allocation licenses or permits that evolve and change according to current needs and circumstances. In the UK, an environmental impact assessment needs to be carried out for projects involving an abstraction of water above 20 cubic meters over a period of 24 hours [69]. Over-abstraction is punished by law and can lead to criminal and civil sanctions such as prosecution and fines [69], [70].

To increase the supply, new water supply and desalination plants are sometimes necessary to face periods of droughts [28]. However, in the UK, the supply of water generates costs, energy usage and a carbon footprint that can hinder the increase of supply [71]. Moreover, because reservoirs are a storage medium widely used by water companies in the UK, increasing the water supply requires the flooding of valleys to form new reservoirs and can have negative consequences on the environment, the population and the public relations of water companies [72]–[76]. Additionally, innovations such as water reuse or desalination face different challenges; the lack of funding - as investment in R&D in the water sector can be low, the compliance with health regulations and the need for support from regulators and politicians [71], [77]. The provision of insufficient rewards for innovation by regulatory regimes often restricts the R&D [71]. Moreover, in addition to being expensive, the development of innovative water resource solutions is energy intensive [78]. Desalination, for instance, involves high energy and production costs [78], [79]. Increasing the water supply while constraining energy usage therefore requires

support, both financial and from the regulatory authorities [71]. While it is a solution to consider to counteract current pressures on the UK water supply, it is an energy-intensive approach that can have damaging consequences on the environment. To face pressures on the water supply, reducing demand therefore appears as a more environmentally-friendly and less costly solution.

#### 1.1.3.2. Reducing Demand

While the agricultural and industrial sectors are known to be among the biggest water users in the UK, decreasing mining and industry activities led to a reduction in non-potable water demand [31]. Yet, water consumption in the UK has risen in the past 25 years and households now use 50% more water than they used to before [80]. Nowadays, the average consumption of water per capita and per day amounts to 150 litres [59]. Household water demand in England and Wales represents half of the public water supply use (52%) [24]. Domestic water consumption is therefore a growing concern in the UK [31]. After the 2006 drought, the Government's water strategy shifted from crisis management to 'demand management and long-term changes in consumption behaviour' [25]. This is in line with the European Commission's recommendations that prioritise actions on water demand management to reduce the pressure on the water supply [81].

To do so, the Commission recommends raising water users' awareness to prevent water scarcity and to "promote and impose the use of domestic water-saving techniques" [81]. It also advocates the monitoring of water demand, the implementation of individual meters and the development of pricing policies to punish excessive water usage [81]. Thus, solutions to the global water crisis are moving away from the reliance on increasing supply by finding new sources of water and reducing domestic demand for potable water now appears as a solution to improve water management [31], [82], On a practical level, reducing demand is an option that is economically and environmentally interesting and that doesn't require major infrastructure changes, contrary to an increase of the water supply [31], [83]. While the implementation of structural changes to reduce the water demand in the UK is currently limited (Section 1.1.2.2), these potential measures should be used in conjunction with psychological and voluntary approaches to generate long-term changes in individuals' behaviours and sustainable reductions in water consumption [41], [44].

#### 1.1.3.3. Behaviour Change to Reduce Water Demand

To better face consequences of climate change, there is a need to integrate social sciences to the water industry [31]. More specifically, reducing water demand can be achieved by identifying and changing consumers' behaviours [84]. Consumers' behaviours indeed play a key role in the achievement of sustainable development [16]. Thus, for [107], behaviour change is the

"cornerstone of sustainability". It is defined as 'any action that an individual *purposively* and *consciously* takes that represent a change from previous actions'[16]. Behaviour change can help achieve long term sustainability of the water sector within urban areas by reducing water demand through the promotion of water and energy savings [85]. Occupants' behaviours are indeed one of the main factor increasing water consumption in buildings in the residential sector [86]. Up to 75% of the reductions in water consumption and water costs can therefore be achieved through behaviour change [87]. In the UK, behaviour change is part of the Government's strategy to encourage the 'sustainable development in the water sector' [25]. The 2008 Framework for Pro-Environmental Behaviours and the 2011 Water White paper highlights the importance of behaviour change to use water more efficiently and suggests the implementation of water-saving habits [24], [35], [41].

Due to growing water scarcity, countries like the USA and Australia have already conducted many studies to develop innovative techniques to encourage water conservation through behaviour change [89]–[92]. Between 1980 and 2006, 72% of the empirical studies related to water demand management came from these two countries [93], [94]. These studies aim at finding ways to change people's water usage and decrease households' water consumption often in a context where resolving water issues is a governmental and societal priority. Australia and the USA have indeed implemented successful measures to reduce their overall water consumption [95], [96], [97]. These studies give useful insights as to the encouragement of water conservation through behaviour change.

However, water consumption in those countries differs from water consumption in the UK. Additionally, water issues are not currently a governmental priority. The rainy climate also means that the population is less educated about water issues and less likely to put efforts into saving water [30], [36], [46]. Individuals act when the threat to water availability is immediate but are less likely to accept measures that reduce the long-term damages on water resources [29]. Thus, while personally experiencing water shortages and scarcity encourages water-saving behaviours, the 2006 droughts in South England only engendered short-term behaviour change [2], [11], [29], [85], [98].

To date, the research on behaviour change to promote water conservation has therefore tended to focus on water-scarce countries but little is known about the effect of such measures in a context specific to the UK. More specifically, to the best of the author's knowledge, there has not been sufficient research determining the best ways to achieve water conservation through behaviour change in the UK. This research contributes to this area of research through the analysis

and validation of methods of behaviour change implemented through ICT to encourage water savings in the context of the UK.

#### 1.1.3.4. Using Technological Advances

Developing sustainable urban water systems requires initiatives to reduce water demand combined with changes in technologies [33], [66]. Technological advances are now considered as potential solutions to the water crisis [82]. Indeed, novel technologies allow individuals to make the most of fewer water resources and to use water more efficiently [12], [99]. The European Commission believes that information and communication technologies can improve water management and has funded multiple European research projects on smart water meters under the 7th Framework Programme for Research and Technological Development (FP7) [100], [101]. The second set of these projects launched in 2014 aims at increasing end-users awareness and promoting behaviour change through these technologies [102]. Indeed, coupled with behaviour change, technical changes can lead to a 30% reduction in water usage [87].

Integrating the advantages of the latest technologies, such as ICT, to easily acquire data about consumer usage and to provide consumers with personalised information concerning their consumption can promote water conservation and behaviour change in the UK [103]–[108]. It can also ease the communication between water companies and consumers. This is crucial as the UK government now encourages water companies to increase their interactions with their customers to promote water conservation [41]. However, the use of meters alone cannot drive changes in behaviour and the implementation of in-home displays, described as "smart-meter connected device that typically presents consumers with real-time (or near real-time) information on water use" is necessary to encourage a "greater response" in consumer behaviour [41], [104], [106]. Initial roll-outs of smart water meters by some water companies in the UK demonstrate that these tools, coupled with the provision of adequate information can lead to significant water savings [28], [105], [109], [110].

## 1.2 Statement of the Problem and Scope of the Study

Existing research has focused on finding solutions to water scarcity in countries affected by water shortages. This has led to an increase in consumer education, to an extended use of water saving devices and to better governmental regulation. There is however a lack of research related to the best ways to promote water conservation in countries that do not appear to suffer from water scarcity at first sight [31], [104], [106]. This is the case in the UK, a country that is well-known for its heavy rainfalls.

The current increase in consumption and the stress on the UK water supply require necessary changes in domestic water usage. New ideas about comfort and cleanliness along with the development of more intensive water-consuming habits and appliances contribute to increased domestic water consumption [36], [65], [111]. On the other hand, growth in population and expanding housing developments increase the risk of water shortages in regions where demand for water is high but where resource availability is already low [29].

Household water demand in England and Wales has risen in the past 25 years and now represents half of the public water supply use (52%)[24]. Reducing domestic water demand is therefore considered as a solution to address water issues in the UK [25], [31], [80], [83]. Studies have shown that changing consumers' behaviours and promoting domestic water conservation can efficiently reduce water demand [93], [94]. Moreover, technological advances can now be used as tools to encourage individuals to use water more efficiently [12], [82], [87]. These methods are currently studied and implemented in countries affected by water scarcity [89]–[92]. However, to the best of the author's knowledge, there has not been sufficient research to determine the best ways to achieve water conservation and behaviour change though the use of ICT in the context of the UK.

This research project fills this gap by assessing the impact on users' water consumption of selected behavioural strategies communicated through an informative user-interface. While structural changes and the retrofitting of efficient water-savings devices within households is discussed, this study is narrowed down to promote water conservation through the use of an interface, deployed on an electronic tablet through the whole trial, without the implementation of additional water-saving devices. Other types of strategies or interventions, e.g. educating users at home or in schools or retrofitting campaigns, are not examined in this thesis. This will help determine whether the sole use of ICT can help achieve reductions in domestic water consumption in the UK by encouraging behaviour change and sustainable water usage. However, due to its exploratory nature, this research provides different courses of action that can inform future practice and policy changes.

The research is also focused on individuals' water consumption in Cardiff, as opposed to agricultural and industrial water usage. It solely intends to encourage water savings in domestic and office settings. The emphasis is therefore on reducing water usage within households and offices and not on changing individuals' use of virtual water or their water footprint, even though these notions are also discussed within this thesis.

## 1.3 The WISDOM Project

This research project has been carried out in the context of the WISDOM project, under the EU 7th Framework Program. Factors such as increasing urbanization, population growth, and the deterioration of existing water infrastructure in the UK make it necessary to efficiently manage water resources and to reduce water consumption in urban areas [26]–[28], [30]–[32]. Monitoring and controlling the water network, using technologies that can analyse real-time water network data and provide optimized configurations of water network assets, can enable a better management of water resources by balancing the needs for water demand and provision. To this end, the WISDOM (Water analytics and Intelligent Sensing for Demand Optimised Management) project aims at developing and testing an intelligent ICT system that enables "just in time" actuation and monitoring of the water value chain from water abstraction to discharge. On a higher level, the WISDOM project intends to (a) increase user awareness and modify behaviours concerning the use of water, (b) achieve quantifiable and significant reduction of water consumption, (c) achieve peak-period reduction of water and energy distribution loads, (d) improved resource efficiency and business operations of water utilities due to ICT, and (e) contribute to the improvement of the environmental performance of buildings. The research described in this thesis has been fully integrated into the project results, contributing to the social aspects of the project and to the fulfilment of its three first objectives.

In addition to contributing to the WISDOM's projects results, WISDOM partners also assisted with this research. Firstly, they distributed the Ask Cardiff (Appendix A) and WISDOM (Appendix B) questionnaires designed by the author (Chapter 6) and collected results for the author to analyse (Chapters 5, 7). Secondly, the structured interviews conducted with end users (Appendix G), designed and analysed by the author, were physically conducted by a specialised consultancy company. Finally, the IT systems, including the smart meters, developed by some of the partners, allowed the collection of data for the office trial.

## 1.4 Aim and Objectives

By encouraging domestic water savings through the implementation of behavioural strategies using ICT, this study contributes to finding solutions to the growing water demand in the UK. It will identify the most efficient behavioural strategies to encourage water savings in households and offices. On a practical level, it will contribute to the understanding of current levels of awareness and current attitudes towards water usage in this country. It will also help determine whether ICT, and more particularly a user interface, is an adequate tool to promote behaviour change and encourage water savings. Based on the literature and on the result obtained from the surveys, the interface has been designed to include different behavioural

strategies to encourage larger water savings and appeal to different users' interests. This research will therefore make a contribution to research on the use of ICT to promote water conservation and extend what is known about the applicability of behaviour theories to encourage sustainable water usage.

The thesis will fulfil the following aim: **Understand whether a user-oriented on-line water feedback system is able to foster improved water-saving behaviours through the promotion of increased awareness of water consumption and the encouragement of positive behavioural and lifestyle changes.**

To do so, five objectives have been formulated;

- Objective 1: Identify water users' current level of awareness of their water consumption and attitudes towards water usage.

Behaviour change implies (a) choosing the ultimate behavioural target, (b) selecting appropriate behaviour change strategies and (c) developing these strategies [112]. Identifying consumption habits and behaviours and the factors influencing them is thus a first step in achieving behaviour change [84], [112]–[114]. In the context of this research, it seems crucial to understand the population's current level of awareness and attitudes towards water consumption (a) to effectively encourage behaviour change, (b) to design the interface accordingly and (c) to assess the interface on users' awareness, attitudes and water consumption. This stage is both exploratory and descriptive. Collecting this baseline information is necessary to understand and identify the attitudes and behaviours that need to be targeted to encourage water conservation and to assess changes in attitudes and behaviours before, during and after the trial. Thus, OBJ1 is addressed in Chapters 5 and 8 through an analysis of people's perceived need to use water more sustainably, their current perceptions of their own water usage and their perceived self-identity. This is done through online questionnaires sent to self-selected samples of the population, and through a water consultation conducted in some households in Cardiff.

- Objective 2: Assess the current level of preparedness for change among water users.

It then appears necessary to estimate individual's level of preparedness for change. This is crucial to determine whether they feel the need and are willing to implement changes to their daily life to reduce their water consumption. It is predicted that the current state of people's preparedness for changes regarding their water consumption will encourage the implementation of conservative initiatives (Chapter 5).

This is assessed through individual's current reported water habits, their willingness to change their habits and to use and invest in a device that can help them save water. Similarly to OBJ1, this is done through questionnaires and a consultation.

The design of these initial questionnaires follows an action research process (Chapter 4). The results from the first questionnaires influence the design of the following surveys to deepen the understanding of some of the answers provided and better reach OBJ1 and OBJ2 (Chapter 5).

- Objective 3: Identify the methods of encouraging behaviour change and water savings that are most effective across consumers with differing views.

Results from the initial surveys, the literature on the subject and the theoretical framework inform the design of the interface and the selection of behavioural strategies (Chapter 6). The most efficient strategies to increase people's awareness of their consumption and promote water conservation are then determined through the trial and validation of the interface by users.

OBJ3 is reached in Chapters 5, 6 and 7 through the evaluation of the impact of tips and advice and of environmental, social and economic information on people's behaviours. This include assessing individual's perception of social influence, their financial interests, their environmental knowledge before and after intervention and their response to the tips and advice provided. It also requires evaluating whether increasing people's awareness of their own consumption can encourage water conservation. This is done through a preliminary water consultation and through the trial of the interface by water experts and end users.

- Objective 4: Determine whether the use of near real-time user-orientated water feedback system promotes behaviour change and water conservation.

While it is necessary to determine the most efficient strategies for behaviour change, it is also crucial to understand whether the user-interface is an adequate tool to promote this change and encourage water conservation. This is the evaluative stage of the research process.

Fulfilling OBJ4 requires an understanding of whether the use of ICTs is adapted to promote water conservation and behaviour. This is assessed through individuals' use of new technologies, their interaction of the interface and its impact on their water consumption. This is assessed during the trial phase of the project that aims at implementing, assessing and validating the use of this tool by users in a domestic and an office setting.

## 1.5 Limitations of the Study

To date, research on the use of ICT to promote domestic water conservation has been mainly conducted in developed countries affected by water scarcity [89]–[92]. Yet, little is known about the impact of these tools in countries like the UK, where water seems abundant and where water shortages are not yet an urgent issue [31], [104], [106]. To fill this gap and to better manage prospective water issues, it therefore seems crucial to understand how ICT can promote water savings in this specific context. The availability of water resources in the region of Cardiff is similar to the level of water availability in most of the UK, apart from the South East of England [35], [69], [519]. Results of the first survey of this project (see Chapter 5) also show that the socio-demographic characteristics of Cardiff inhabitants and housing trends in this city are in line with national statistics, as discussed in Chapter 8 [58-59], [518]. These socio-demographic characteristics include factors that have been identified as the most likely to influence water behaviours after a review of the literature. As a result, characteristics such as age, gender or level of income were assessed. Conversely, religious factors, which are not commonly studied in literature, did not appear as one of the main socio-demographic characteristics affecting water consumption and were therefore not considered. While this can be perceived as a limitation, the reported socio-demographic characteristics of Cardiff inhabitants and the climatic features of the city still indicate that Cardiff is a good testbed for this research project and that the results could be generalised to the UK. Moreover, Cardiff was chosen as a pilot case study in the context of the WISDOM project (see Section 1.3). Existing relationships between Cardiff University and Welsh partners of the project, including Cardiff City Council and Welsh Water, also made it natural to study the population of Cardiff as part of this research project.

However, while the characteristics of Cardiff inhabitants might be representative of the global population of the UK, the small sample sizes used in the context of this study and the choice of sampling methods limit the generalisability of the results, as explained in Chapter 8. In order to reach larger samples of population, a self-selection sampling method was used to recruit participants to the surveys (see Chapter 4). This method is commonly-used in social sciences research but can generate biased responses [413], [449]–[451]. In this thesis, this means that, apart from respondents to the first survey, participants might have had an initial interest in water consumption (see Chapter 8). Their responses might suggest a positive environmental bias that is not representative of the global population. Finally, the small sample size of the water consultation, of the case study with end users and in the office setting and of the focus group does not allow generalizations (see Chapter 7). Considering these limitations, the results should be interpreted with caution. They however give more insights than existing work regarding the use

and acceptance of ICT to promote behaviour change and water conservation in the UK [31], [104], [106].

## 1.6 Overview of the Thesis

In the remainder of this thesis, Chapter 2 lays out the background theoretical dimensions of this research by reviewing behaviour-building theories and behaviour-changing theories applicable to environmental behaviours [115]. These theories provide recommendations regarding strategies that can be adopted in order to change individuals' behaviours. Chapter 3 then reviews the different types of strategies and approaches that can be implemented to put these theories into practice. It demonstrates that behaviour change can be achieved through psychological approaches, coupled with structural changes. Nowadays, studies conducted in water-scarce countries have shown that ICT is an efficient tool to bring these psychological strategies into individuals' everyday life. The present study fills a gap in the literature by analysing and validating different methods of behaviour change and by studying the use of such tool to encourage water savings in the context of the UK.

Drawing on these two preliminary chapters, the methodology described on Chapter 4 explains the methodological approaches used in this research. Due to the interdisciplinary nature of this research project, both quantitative and qualitative methods are used to investigate the implementation of ICT to reduce water consumption in the UK. These methods include surveys, structured interviews and a focus group. Prior to implementing and validating the interface, initial surveys were conducted to obtain baseline information about individuals' attitudes towards water consumption and awareness of water consumption in the UK. Chapter 5 describes the preliminary results obtained from these surveys. Based on an action research process, these results and the literature described in Chapters 2 and 3 influenced the design of the user-interface and the choice of behavioural strategies used, as explained in Chapter 6. The content of the interface revolves around the environmental, social and financial aspects of water consumption.

To understand the impact of the interface, different trials have been conducted with water experts and end-users at home and in an office setting. The author believes that conducting these trials is crucial to implement and validate the interface in a real-life context and to understand its influence on water consumption, and on individuals' awareness and knowledge of water issues. Results from these trials indeed provide an better understanding of the impact of the interface and its use, as described in Chapter 7. Chapter 8 discusses the findings obtained in light of the literature and provides insights to fulfil the four objectives aforementioned. Due to unforeseen circumstances, it was impossible to implement and validate the interface in households over a long period of time. However, the results obtained from the trials are promising and suggest that

further research is needed on this subject. Thus, Chapter 9 offers a recommended methodology to expand the work carried out in the context of this project. It also provides suggestions for future work to test the impact of social and financial behavioural strategies in a domestic setting. Chapter 10 concludes this thesis by providing a summary of the work accomplished and by fulfilling the aim formulated above.

# Chapter 2: Literature Review Part 1: Understanding the Socio-Demographic & Psychological Factors Influencing Behaviour

Water scarcity is a growing issue affecting developing and developed countries [7], [116]. In UK urban areas, the growing demand for water and the ageing infrastructure are factors impacting the provision of water [117]. While increasing the water supply can be a solution to these issues, it mainly involves methods that are costly and energy-intensive [71], [77], [78], [118]. Promoting water conservation through behaviour change now seems necessary to better manage the available water resources and to reduce water demand [24], [35], [41], [119]. However, changing behaviours is a challenging process [115], [120]. The difficulty principally lies in the vast number of factors influencing behaviours [120]. Prior to implementing behavioural strategies, it is therefore necessary to understand the drivers of water user's behaviours to (a) target the right population, (b) target the right activities i.e. water-using activities and (c) design appropriate and efficient strategies [112].

Based on the literature on the subject, it seems that a large variety of factors influence water consumption and environmental behaviours at large. However, studying socio-demographic and psychological influences is particularly helpful to understand individuals' water usage [121]. Thus, Section 2.1 describes the socio-demographic characteristics and contextual factors that affect the way people use water [54], [122]. Then, based on the review of various theories, Section 2.2 describes the factors influencing existing behaviours and explains the best ways to develop new behaviours [115], [120]. By drawing together this knowledge, this chapter will identify a set of key factors that need to be assessed on the population studied. Understanding the personal characteristics that influence water consumption will facilitate the design of efficient strategies to encourage water savings in the context of this project. Additionally, as the use of Information and Communication Technology (ICT) is a key element of this research, understanding people's acceptance of new technologies and ways to increase this acceptance is crucial. Thus, Section 2.3 will review relevant theories regarding the adoption of such technologies by the public. This will contribute to establishing the theoretical framework of this research to efficiently use ICT to promote behaviour change (see Chapter 6) and will be considered when designing the surveys aimed at assessing the level of public acceptance of these ICT (see Chapter 7).

## 2.1. Socio-Demographic and Contextual Factors Influencing Behaviours

This section reviews socio-demographic and contextual factors that impact environmental and water-related behaviours. Understanding the nature of water usage is necessary to design and increase the efficiency of conservation measures [123], [124]. Socio-

demographic characteristics are indicators of certain water-using practices [31], [54], [125]–[128]. Thus, through a review of the relevant literature, this section first describes the impact of gender, age, education and income on behaviours [129], [130]. Household characteristics, including the property's characteristics, the housing tenure and the household composition are also reviewed in the first part of this section. Due to their important impact on water consumption, contextual factors affecting domestic water behaviours, i.e the climate of a country and its institutional context, are then described in the second part of this section [60], [63], [125], [130]–[132]. The author believes that the understanding of the personal characteristics that influence water consumption can indeed facilitate the design of efficient strategies to encourage water savings through ICT.

### 2.1.1. Socio-Demographic Factors Inherent to Individuals

Despite a noticeable lack of consensus on the matter, the impact of socio-demographic factors on water consumption has been widely discussed in the literature [11], [63], [64], [125], [131], [134]-[136], [149]. Following a review of various studies, this section describes the socio-demographic factors found to influence environmental and water-related behaviours internationally and in the UK. These factors are directly related to individuals or to their households [11], [63], [64], [124], [130], [133]–[137].

#### 2.1.1.1. Gender

In terms of gender, women are considered as being more emotionally engaged and concerned about environmental issues [130]. They hold stronger attitudes towards environmental quality than males [138]. Thus, they are more likely to perform and engage in environmentally-friendly behaviours and water conservation behaviours [133], [139]. For this reason, the higher the percentage of males in a household, the less pro-environmental habits are generally undertaken within this household [140]. However, the impact of gender varies depending on the country and its cultural values. For instance, [11] found that the levels of environmental beliefs between men and women were similar but affirmed that women use more water than men. This could result from the fact that, in Mexico, where the study took place, women spend more time at home and are usually more involved in domestic tasks [11].

#### 2.1.1.2. Age

The impact of age as a factor influencing environmental behaviour is also argued within the literature. Overall, as [133] points out, older studies tend to consider younger generations as being pro-environment [141]–[143]. Conversely, newer studies find older generations to be more environmentally concerned than younger generations [11], [129], [133], [144], [145]. This can be

explained by the fact that younger participants of older studies are falling into older age categories in recent studies [133].

For instance, for [11], younger individuals are less inclined to develop sustainable habits because they are less 'future-oriented' than adults [11], [85]. Yet, developing a sustainable way of life requires a certain degree of 'future orientation' [11]. In practice, it appears that residential areas with a high proportion of young population tend to use high levels of water due to frequent laundering and outdoor water usage [144], [145]. In line with this, [133] affirms that older generations are more inclined to take part in water conservation activities. However, households including a higher proportion of people over 65 years-old seem less likely to invest in water-saving appliances [140]. This does not necessarily reflect a lack of involvement in water conservation activities and can be explained by the fact that older generations grew up without having the modern appliances that are available now [140]. They developed low-technologies conservation habits, such as plugging the sink when washing dishes, that do not require the use of such appliances [139], [140]. For [139], the correlation between high age and environmental behavior results more from a cohort or generational effect than from an age effect [139]. Generational cohorts, defined as a set of people born at the same time, are united by important historical events occurring between the age of 17 and 25 [133], [146], [147]. This explains the involvement in conservation activities of generations who grew up in the 1970s and in 'the rise of environmentalism and environmental issues' [133], [139].

However, paradoxically, older generations' beliefs tend to be in line the Human Exception Paradigm, which states the idea that humans are above nature and can use up its resources in an arbitrary way, whereas younger people express high levels of ecological beliefs [148], [149]. In conclusion, younger generations are more inclined to think that they are damaging the environment in the abstract but are less likely to behave in a sustainable way in practice [150]. Conversely, older generations are less likely to develop environmental beliefs but are more inclined to adopt sustainable behaviours [150].

#### 2.1.1.3. Education

Concerning the effect of education, consumers with a higher level of education tend to be more educated and to know more about environmental issues [130]. Educated people also save water more regularly and educated households are more likely to engage in pro-environmental behaviours [64], [140]. Yet, education does not always have a significant impact on water conservation behaviours and cannot predict those behaviours for certain [130], [133]. Indeed, having more knowledge about environmental issues does not necessarily increase one's involvement in environmental behaviours [130], [133].

#### 2.1.1.4. Income

Just like age and gender, the income of the household is another debated factor. Higher incomes sometimes predict water conservation behaviours [133]. In a survey about the implementation of an oncoming conservation program, [134] first found that people with higher income were more inclined to engage in water conservation campaigns due to their ability to integrate technological changes in their daily life and to the fact that they had more spare time to practice environmental behaviours. While it appeared that these people did not respond more favorably than others to conservative measures once the program was put in place, [133] came to similar conclusions and stated that people with higher incomes tend to save more water because they have more time and resources to perform environmental behaviours [133], [134]. Indeed, these persons can afford to buy and use water-saving technologies that help them reduce their consumption [2], [54], [135], [140].

Conversely, other studies found that higher incomes lead to higher levels of water consumption [125], [148]. Indeed, higher incomes imply bigger houses, gardens and swimming pools, and thus, encourage high water consumption, especially outdoor [54], [63], [64], [148]. For [127], people with higher incomes also tend to underestimate their water use. In addition, they are less motivated to reduce their consumption for economic purposes whereas people with lower incomes are often encouraged to save water to reduce their bills [2], [134], [135], [148].

#### 2.1.1.5. Household's Characteristics

Household's characteristics, including the property's characteristics, the housing tenure and the household's composition, all have an influence on water consumption [54], [63], [148].

Concerning the property's characteristics, water conservation is generally associated with smaller properties [124]. People owning large houses, gardens or swimming pools have a greater chance of performing water-using activities such as watering lawn and gardens [54], [63], [148]. Conversely, people living in flats have been found to use less water [63], [148]. Concerning the housing tenure, people with higher income are more likely to own their house and thus, are more inclined to invest in water-saving devices [140]. Indeed, investing in water saving devices allow house owners to reduce their water bill and benefit from such investment on a long term [135], [140]. Additionally, it also adds value to their house [135], [140]. House owners are also more likely to be more aware of the price they pay for their water usage, contrary to people who rent their properties or share houses who often pay common bills to their landlord [63].

Finally, regarding the composition of the household, several studies came to the conclusion that having a large household is a factor promoting water consumption [2], [148]. The presence of children in the household requires more washing and frequent toilet usage [125]. It also reduces

the likelihood of the household having water saving devices, such as low volume toilet and low volume showerhead installed [54]. Similarly, the presence of teenagers significantly increases the volume of water used for showering purposes [151]. On another note, larger families with young children are more likely to underestimate their water consumption [127].

#### 2.1.1.6. Situation in the United Kingdom

The author believes that comparing global socio-demographic trends with trends within the UK population is necessary to better understand the context of this research project. Looking at the literature, it appears that the socio-demographic factors influencing environmental actions and water consumption in the UK are in line with the factors reported in international studies. Based on the 2006 study conducted by Gilg & Barr on 1265 British households, the engagement of women in environmental behaviours in the UK follows expected trends. Women are more committed to undertaking water-saving activities and are more likely than men to adopt pro-environmental behaviours in general [124], [152]. Findings related to the impact of age on environmental behaviours also showed that older consumers were more likely to perform environmental behaviours than younger consumers [124], [152]–[154]. The 2016 Consumer Council for Water Report indeed reported that young persons are less likely to make a conscious decision to use less water [124], [152]–[154].

Concerning education levels, [121] found, in their "Understanding Society" survey conducted on more than 20.000 participants, that people with higher levels of education are more likely to adopt pro-environmental behaviours, i.e. paying more for environmentally-friendly products. More specifically, committed environmentalists – people who engage in water saving activities – are more likely to have a degree than non-environmentalists or occasional environmentalists - people who perform some water saving activities but are less committed [121]. Concerning income levels, non-environmentalists are on significantly lower incomes than individuals committed to such behaviours [124]. Indeed, households with lower employment status spend more on water per week than households with higher employment status [31].

Committed environmentalists have smaller household sizes than occasional or non-environmentalists [124]. They generally live in terraced properties unlike other environmentalists who mostly live in semi-detached homes [124]. [153] found that detached houses lead to higher weekly water consumption levels, perhaps due to outdoor water usage for gardening purposes. Conversely, people living in semi-detached houses are more likely to use less water [153]. Regarding housing tenure, [153] found that environmentally-committed individuals own their own home, contrary to non-environmentalists that are usually private tenants. House

owners are also more likely to make a conscious decision to use less water in order to save money on their water bill [153].

This section reviewed the socio-demographic factors found to influence environmental behaviours worldwide and in the UK. First, it seems that, both in the UK and internationally, women, older and educated persons are more likely to save water [11], [64], [121], [133], [139], [140], [155]. While the impact of income on behaviours is still debated in the literature, in the UK, higher income was found to lead to pro-environmental and water-saving actions [31], [54], [63], [64], [121], [133], [134], [148]. Regarding the household characteristics, people living in small properties, house owners and smaller households also tend to use less water [2], [63], [121], [125], [127], [140], [148]. In addition to socio-demographic factors, contextual factors also influence water consumption and need to be considered [60], [63], [125], [130]–[132]. The section below therefore reviews the contextual influences that most impact consumption, in the UK and worldwide.

### 2.1.2. Contextual Factors

This section reviews the contextual factors found to influence environmental and water-consuming behaviours. Contextual factors are here understood as factors that are not directly linked to the individuals but that participate in shaping their behaviours. They mainly include characteristics that are specific to the country in which people live, such as climatic conditions and institutional contexts. Understanding these factors and their impact on individuals is necessary to efficiently manage water [2], [60].

#### 2.1.2.1. Climatic Conditions and Weather

Water usage is not stable over time and can vary depending on the weather or on the seasons [93], [156], [157]. Due to their inelasticity, the level of fluctuation of indoor water activities is often found to be low [126], [151], [158], [159]. However, outdoor water consumption is likely to increase during the summer months, especially in warm countries [52], [160], [161].

Personally experiencing water shortages increases people's willingness to change the way they use water [98]. The more motivation people have for saving water, the more they will engage in water-conservation activities [11]. As a result, people living in water-scarce areas put greater effort into saving water in time of scarcity and are generally more concerned about water conservation [2], [11], [85], [98]. They know that making conservation efforts is beneficial to them and to people living in their areas [11]. The effectiveness of water-saving measures therefore varies depending on the climatic conditions of the area in which they are implemented [2].

Additionally, seasonal changes and the local weather sometimes increase individual's awareness of environmental issues and influence the investment in water-saving devices [98], [140], [156]. The rising sales of smart water meters in the last few years in the USA, Spain or Israel are a perfect example of this [162]. Concerning seasonal changes, Summer usually tends to increase the installation of swimming-pools while Autumn encourages the installation of watering systems [156]. The investment in an appliance in response to a specific environmental problem can also lead individuals to invest in other efficient devices [140]. This could explain the fact that, surprisingly, in Spain, [140] found that more rainfall seems to increase the probability of buying water-efficient washing machines.

#### 2.1.2.2. Institutional Context

In this section, the author explains how the institutional context in which people live also plays an important role in inducing environmental behaviours. By educating people and encouraging the development of more sustainable behaviours, governmental campaigns efficiently encourage water conservation [54], [148]. Complying with a conservation campaign can initiate further engagement in water-conservation practices [148]. In their study, [54] found that the promotion of water-saving appliances by the government increased individuals' willingness to reduce their indoor water usage. Norms requiring water savings and punishments for excessive consumption also encourages water conservation [148]. For instance, in Australia, 75% of the Sydney residents interviewed changed the way they use water after the enforcement of water restrictions [163]. Implementing restrictions on activities such as car washing or gardens watering also impact indoor water usage and the use of showers or washing machines [63]. However, regulations do not always increase the motivation to save water as individuals respect the imposed limitations but do not go further in their conservation efforts [2].

This section presented the main contextual factors influencing water consumption and conservation. Water scarcity leads to increased concern, engagement and education about water issues. Seasonal changes and local weather conditions also influence water consumption, especially outdoor, and the purchase of water-saving appliances. Institutional initiatives such as large-scale conservation campaigns, restrictions and punishments can help promote water conservation on a large-scale. However, as described in Chapter 1, the UK climatic conditions and the non-urgency of water-related problems in this country tends to hinder governmental initiatives and the development of education and conservation measures [30], [36], [46]. It is therefore necessary to determine the best way to encourage water-saving behaviours despite the current lack of political initiatives in this country. Thus, the following section describes the psychological factors that need to be considered to design efficient voluntary and psychological methods of behaviour change.

## 2.2. Psychological Factors: Model of Behaviours and Behaviour Change Theories

Contextual and socio-demographic characteristics help understand environmental behaviours [130]. However, it is not enough to predict final water usage [123]. In order to better understand individuals' water consumption, psychological factors have to be reviewed alongside these factors [164]. Determining people's behaviours, attitudes, beliefs, values and habits is crucial to understand and encourage environmental actions. These concepts are the core of many theories aiming at explaining behaviours. By describing the internal influences encouraging people to adopt – or not adopt – certain behaviours, these theories help understanding the mechanisms that drive environmental actions. The author believes that they provide useful guidelines to develop efficient strategies to promote behaviour change in the context of this study.

This section focuses on the theories that are particularly relevant in the context of this research. Due to the large number of applicable theories, the following section is divided into ten parts, revolving around ten different factors commonly found to influence behaviours (see Table 2.1).

Table 2-1. List of psychological factors and relevant theories.

| **Theoretical Construct** | |
|---|---|
| 2.2.1. Attitudes & Intentions | Theory of Reasoned Action<br>Theory of Planned Behaviour |
| 2.2.2. Habits | Theory of Interpersonal Behaviour<br>Attitude-Behaviour-Context Theory |
| 2.2.3. Values | Value Theory<br>Value Action Gap |
| 2.2.4. Personal Norms | Norm Activation Model |
| 2.2.5. Beliefs | New Environmental Paradigm & The Human Paradigm<br>Value-Belief-Norm Theory |
| 2.2.6. Economic reasoning | Rational Choice Theory<br>Prospect Theory |
| 2.2.7. Knowledge | Information Deficit Model<br>Knowledge Action Gap<br>Model of Responsible Environmental Behaviour |
| 2.2.8. Identity | Cognitive Dissonance Theory<br>Lewinian principle<br>Self-Discrepancy Theory<br>Symbolic Self-Completion Theory<br>Self-Perception Theory |
| 2.2.9. Social Environment | Social Cognitive Theory<br>Social Learning Theory<br>Other person principle<br>Identity Theory<br>Social Identity Theory |

As they form the basis of many behavioural theories, the Theory of Reasoned Action and the Theory of Planned Behaviour, explaining the impact of attitudes and intentions on behaviours, are first described [165], [166]. While they are now commonly applied to environmental behaviours, these two theories have been extended through the development of other theories that demonstrate the influence on behaviours of factors such as goals, habits, values, personal norms and beliefs (See Table 2.I) [165].

### 2.2.1. Attitudes & Intentions

The Theory of Reasoned Action and the Theory of Planned Behaviour, developed by Ajzen & Fishbein, explain how attitudes and intentions predict behaviours [166]. Nowadays, these theories are two of the most-commonly applied models in the study of environmental behaviours [165], [166].

#### 2.2.1.1. The Theory of Reasoned Action

The Theory of Reasoned Action was described by [167]. It assumes that individuals are rational and are not controlled by 'unconscious motives or overpowering desires' [130], [167], [168]. Human behaviours that are under voluntary control are directly influenced by intentions, that are themselves influenced by attitudes and subjective norms [167], [169]–[172].

Attitudes towards a behaviour refer to the positive or negative evaluation of the outcome of a behaviour based on material, social or psychological consequences and of the likelihood of this outcome [170], [171]. Following this theory, environmental attitudes lead to environmental behaviours [64], [130]. People are indeed more likely to engage in a behavior if they consider that their actions will have a positive impact on the environment [7], [85], [173]. Thus, individuals with positive environmental and water conservation attitudes use less water than those with less positive attitudes [64], [130]. However, attitudes and behaviours are connected at the same level of specificity [149]. As an example, recycling can be best predicted by a set of recycling attitudes rather than by a set of general environmental attitudes [148].

Subjective norms or social norms are the perceived social pressure to perform a behaviour or the "perceptions that certain behaviours and attitudes are considered typical or desirable" within a community [167], [171], [174]. It implies that individuals value social relationships and behave according to what they think is socially desired [175]. They want to give a positive image of themselves to members of their social group [176]. Therefore, increasing people's awareness of social norms can help shape behaviours [177].

For [173], there are two types of social norms: (1) injunctive norms (doing what others think one should do) and (2) descriptive norms (doing what others do). First, people engage in a behaviour

if they have a positive attitude towards this behaviour and believe that their peers expect them to act in a certain way [7], [173]. In that sense, the decision to perform a behaviour can reflect an individual's perceptions of the personal and social consequences of their actions [179], [180]. Then, behaviours are influenced by what others do [179]. Situational cues therefore play a crucial role in informing about others' behaviours [88]. For instance, seeing others engage in a compulsory water conservation campaign encourage people to cooperate with the conservation effort [11]. Similarly, comparisons with neighbours' water usage, also encourage water conservation [63], [181]. However, situational cues have a reverse effect when many people openly violate norms [88]. Indeed, witnessing others wasting water can reduce individuals' conservation efforts [2], [182]. Observing negative behaviours can also lead people to think that environmental issues are caused by others and that they should not be held accountable for them [63]. If people believe that the costs of environmentally-responsible behaviour is not equally shared by others and if they feel that their actions alone do not have enough impact, they can be reluctant to act [179]. Collective action is then difficult to obtain [179].

Performing a behaviour also depends on the difficulty of performing the behaviour and on the resources and opportunities it requires [176]. Therefore, intentions to act pro-environmentally are not only influenced by attitudes and subjective norms but also by one's "own perceived competency" to perform a behaviour [177]. The addition of constraints or control beliefs, as determinants of behaviour in the Theory of Reasoned Action resulted in the development of another theory: The Theory of Planned Behaviour [170], [171], [176].

#### 2.2.1.2. The Theory of Planned Behaviour

In line with the Theory of Reasoned Action, the Theory of Planned Behaviour (TPB) considers that behavioural intentions predict future behaviour [171], [172]. Yet, in addition to attitudes and subjective norms, these intentions are also being determined by one's perceived behavioural control or by the conviction that one has the required skills and resources to perform the behaviour [7], [172], [177], [183], [184]. Perceived control includes people's locus of control, self-efficacy, feelings of powerlessness, or "moderators" such as gender, socio-economic status, group membership or income [170].

To adopt a new behaviour, individuals need to believe that they have the ability and resources to perform the desired behaviour [7], [184], [185]. For instance, individuals with water-saving skills are likely to reduce their water consumption [11], [186]. However, water conservation is limited when people do not know how to reduce their usage [90], [186]. Heightening the perception of individual control through the monitoring of people's use of certain resources can be a good way to encourage environmental intentions [177]. Conversely, insufficient behavioural control can

prevent people from taking actions [177]. This lack of control can be due to a lack of skills or to external factors [11], [186].

Situational influences and contextual forces such as regulations or infrastructure, can be drivers or barriers to people's actions either by having a moderating effect on environmental attitudes or by directly affecting ecological behaviours [170], [187]. According to [113], the attitude-behaviour association is the strongest when contextual factors are neutral but is weak when the contextual forces compel and prohibit a behaviour [113], [188]. For instance, if personal behaviours are difficult, time-consuming or expensive, their dependence on attitudinal factor is weak [113]. As an example, the availability of alternatives to driving in cities can encourage the use of such means of transportation [113], [187]. However, restricted options or choices can limit people's ability to reduce the usage of their cars [187].

While the TPB is widely used to explain behaviours, many studies have extended it by adding predictors to behaviours [165]. Indeed, determinants such as habits, past behaviours, personal norms, beliefs, knowledge and identity have been found to impact behaviours either directly or indirectly [171], [177], [183], [187], [189].

### 2.2.2. Habits

Habits are an important concept that should be acknowledged when studying the determinants of environmentally friendly behaviours [113], [188]. They can be defined as "learned sequences of acts that have become automatic responses to specific cues and are functional in obtaining certain goals or end-states" [189], [190]. According to Triandis' Theory of Interpersonal Behaviour, intentions and attitudes can only predict behaviours to the extent that such behaviours are not habitudinal [115], [189], [191]. Similarly, the Attitude-Behavior-Context Theory (ABC Theory) states that habits and routine should be considered as causal variables predicting behaviours. Indeed, environmental behaviours are often the result of personal habits and household routine [113], [188].

As a result, behaviour change implies breaking old habits and practicing a new behaviour until it becomes a habit [113], [130], [188], [192]. Behaviours become automatic or habitudinal when they are repeated in consistent settings, unintentionally, and when they necessitate less control and awareness from the person performing it [193]. However, the automacy does not increase indefinitely and becomes stable after a while [193]. This stability occurs after 18 to 254 days and varies depending on the complexity of the behaviour [193]. Complex tasks have a lower level of automaticity than simple task and can take longer to be achieved automatically [193]. Moreover, it can be harder to change a behaviour if this change requires an important personal sacrifice [48].

Concerning water usage habits, behaviour change can either require no degree of personal sacrifice, i.e. turning off the tap when brushing teeth, require limited personal sacrifice, i.e. turning off the tap when soaping or require more significant personal sacrifice i.e. reducing the number of baths and showers [48]. Thus, the type of behaviour and the difficulty of the behaviour promoted have to be considered when changing habits [112].

It is important to make a distinction between volitional habits and non-volitional habits [132]. Volitional habits are the result of a conscious effort and are developed because they first fulfil a certain goal [132], [190]. In that case, they can be understood as being efficient, initially intentional, controllable to a certain extent and executed automatically [190]. Volitional habits tend to reflect consistencies in people's lives [132], [194]. Environmentally-friendly habits are volitional when they first result from people's intentions to act more sustainably. For instance, frequent and repetitive environmental behaviours, such as taking short showers or washing full loads of laundry or dishes, can become water conservation habits [132], [133]. On the other hand, non-volitional habits are performed without thinking or considering different alternatives [188]. This lack of initial reflexion means that non-volitional habits are often water consuming [132]. Examples of these habits include "washing clothes and dishes" or "watering the garden" [132].

### 2.2.3. Values

In the Value Theory, values are defined as "desirable and trans-situational goals that vary in importance and serve as a guiding principle in one's life" [195], [196]. They are developed at an early stage and remain abstract and stable over time [195]. The strength of values however changes when individuals encounter significant new experiences in their lives, especially over long periods of time, or when their way of life is threaten [88]. Values are influenced (a) by the "micro system" i.e. family and peers, (b) by the "exosystem" i.e media and political organisations and (c) by the "macrosystem" i.e. the cultural context [130], [197]. They serve, most of the time unconsciously, in the evaluation of the consequences of one's behaviour and thus affect attitudes [88], [198]. For instance, behavioural choices that have damaging consequences for one's central values are likely to be negatively evaluated [88], [195], [196].

#### 2.2.3.1. Value Orientations and Their Environmental Implications

Sustainable consumption often involves conflicts between individual and collective interests or between what is personally costly and what benefits others, future generations, nature and the environment [88]. Engagement in sustainable actions therefore depends on how individuals classify and prioritize their values [88], [196], [199]. The Value Theory classifies values according to their orientations and explains their impact on environmental behaviours accordingly [196], [198]. It distinguishes between self-transcendence values, that promote

environmental actions, and self-enhancement values, that hinder such actions (see Table 2-2) [196]. However, attitudes and behaviours sometimes appeal to more than one value and to competing values [198]. Issues appear when people are faced with hedonic values that are opposed to their altruistic and biospheric values [88], [198]. Indeed, sustainable consumption is often costly and can require efforts, money and sacrificing one's comfort [88], [198]. Therefore, it is sometimes incompatible with the fulfilment of self-transcendent values and requires people to exercise self-control to act in line with those values [88], [198].

Table 2-2. Values Orientations

| Self-Enhancement Values | Self-Transcendent Values |
|---|---|
| Egoistic Values<br>Preoccupation for one's own interest and about what affects one personally [179]. | Social Altruistic Values<br>A concern for practices that affect others, i.e. local groups or global communities [179]. |
| Hedonic Values<br>Focus on finding ways to improve feelings and reduce efforts [88]. | Biospheric Values<br>A sense of responsibility for all the living inhabitants of the earth [179]. |

### Self-Enhancement Values

Self-enhancement values refer to egoistic and hedonic orientations [113]. These values are negatively associated with pro-environmental norms and actions [113]. They include obedience, self-discipline or family security [113]. Egoistic values suggest the improvement of one's resources and the removal of suffering and harm from oneself [88]. Hedonic values reflect an interest in improving one's feelings and in reducing effort for oneself [88], [200]. Egotistic and hedonistic persons are less likely to act in an environmentally-friendly way [130], [201]. For instance, driving is more comfortable and requires minimal effort compared to less polluting means of transportation [200]. Egoistic orientation is a motivator for pro-environmental behaviour only when the behaviour serves individuals' needs and wants and when the pro-environmental activities are in alignment with their priorities [130], [179]. However, once their personal needs are satisfied, people are more likely to act ecologically [130], [201].

Nowadays, economic growth, corporate capitalism and feelings of insecurity and competition emphasize the pursuit of self-interest and promote hedonic and egoistic values [88]. Individuals are usually more concerned by their self-interest than by the interest of the community [61], [176]. Personal needs, such as those related to self-esteem, self-efficacy and personal control have to be satisfied prior to performing selfless environmental actions [130], [202], [203]. Likewise, decisions to perform or not perform a behaviour are first influenced by perceived personal

consequences [176]. People develop environmental and altruistic behaviours when they feel that they are going to be personally affected by climate change [176]. The idea of saving water for the greater good is not motivating enough for them to take action, even though everyone will be affected by water scarcity in some way in the future [61]. Issues have to be perceived as directly affecting one's own future generations to have a bigger psychological impact on individuals [176].

### Self-Transcendent Values

Self-transcendent values refer to social orientations described as 'the removal of suffering of other people' and biospheric orientations defined as 'the removal of destruction and suffering in the non-human world' [88], [130], [204]. These values encourage sustainable consumption and it is crucial to strengthen them simultaneously through situational cues [88].

The environment can be considered as "a public good" [113], [205]. Thus, in order to take actions to preserve it, individuals need to develop altruistic motives or to feel sympathy for others [113], [205]. Biospheric values demonstrate an "affective relationship to the natural world" that includes a sense of 'emotional affinity' felt towards nature or feelings of empathy with wild animals [113], [130]. Highly valuing other species implies that one cares about the environmental conditions that threaten them [113]. Individuals with biospheric values feel a sense of responsibility for all the living inhabitants of the earth - either the contemporaries or the future generations - and ethically commit to environmental preservation [179], [195]. They tend to consider the environmental consequences of their choices [88]. The stronger biospheric values are, the most eco-friendly a person is [195].

Similarly, because they focus concern beyond themselves and their immediate social circle, people with altruistic values tend to be more involved in environmental activities [113], [130], [202], [203]. Acting pro-environmentally indeed implies "actively caring" and showing concern for environmental policies and practices that affect others i.e. local groups or global communities [179], [202]. However, behaviours that first appear as social and altruistic can sometimes be motivated by other purposes. According to the Warm-Glow Giving Theory, contributing to the public good gives people a 'warm-glow' or a sense of satisfaction resulting from feelings of prestige and social approval [206], [207]. In line with this, performing environmental behaviours that demonstrate altruism, such as buying a green product, can be motivated by a desire to improve social reputation [208].

As an example, [208] studied the purchase by many Americans of the Toyota Prius car, a hybrid gas-electric vehicle. Even though this car emits lower levels of CO2 and is sold as an environmentally-friendly car, they found that environmental conservation was only the fifth reason leading people to buy it [208]. Indeed, the main reason for investing was that "it shows

the world that its owner cares" [208]. By adopting pro-environmental behaviours, such as buying this car, people show that they are "prosocial" and not "proself" and care more about the environment than about the potential comfort of another car [208]. This, in turn, builds a prosocial reputation that makes them seem friendlier and more trustworthy and gives them a social status that allow them to obtain desirable things more easily [208]. As it can even give oneself the status of leader in some societies, social reputation sometimes generates "competitive altruism" [208]. However, status motives encourage pro-environmental actions only if the action is made public and influences the person's reputation [208]. Likewise, the action needs to be a little costly. For instance, if the green product purchased is cheap, people can think that individuals investing cannot afford costlier products [208]. This would result in the person being perceived as having a lower status and would not have the desired effect on reputation [208].

#### 2.2.3.2. The Value-Action Gap

The Value-Action Gap Theory, first described by [209], refers to a discrepancy between people's environmental concerns and their actions. The value-action gap is also referred to as an attitude-behaviour gap or as a intentions-behaviour gap [130], [210]. It highlights the limited translation of pro-environmental concerns into pro-environmental behaviours [209]. Even though most people in western countries are aware of the impact of human action on the environment, active support is difficult to obtain due to a discrepancy between what people believe in and what they do [183]. Despite being concerned about environmental issues, individuals do not change their behaviours accordingly [211]. Concerning water consumption, the value-action gap characterizes a discrepancy between people's attitudes and intentions towards water conservation and their actual water consumption [2], [123], [134], [212].

[209] defines the three main barriers to action as (a) individuality or the temperament of a person, (b) responsibility to take action and to feel like one can be useful and (c) practicability, including social and institutional constraints [130], [209]. To reduce the value-action gap, these constraints should be considered [209]. However, this gap also results from other factors such as indirect experiences, normative influences i.e. social norms, cultural tradition and family customs, temporal discrepancy i.e. the fact that people change over time and to the different measurements of attitudes and behaviours [130], [213]. Measured attitudes are sometimes broader in scope than measured behaviours which can lead to important discrepancies [130]. For instance, caring for the environment is an attitude that can be translated into multiple actions [130]. Evaluating the sole action of recycling to assess this attitude would be too limited [130]. A person who cares about the environment does not necessarily recycle but can perform various other environmental activities.

### 2.2.4. Personal Norms

Similarly to the TPB, the Norm Activation Model (NAM) is used when studying the adoption of pro-environmental behaviours [214]. According to the Norm Activation Model, personal norms are the basis for individuals' general predispositions to act pro-environmentally and can therefore be considered as direct determinants of environmental behaviours [113], [176], [215]. They have a comparable impact as attitudes on intentions and behaviours which is why their potential integration in the TPB should be examined [171].

Personal norms can be defined as "personal ideas about how one should act" [175]. In other words, they can be understood as self-expectations based on internalized values [215]–[217]. In order to influence behaviours, the activation of personal norms is crucial [215]. Activation happens when people are aware of the consequences of their actions on the welfare of others and when they take responsibility for these consequences [171]. Once activated, personal norms participate in developing feelings of moral and personal obligation that guides a behaviour [113], [171], [217]. This lead people to evaluate environmentally relevant behaviours in terms of right and wrong [171], [218]. For instance, people with biospheric values tend to be more aware of the negative environmental consequences of their behaviour [88]. This increases their feelings of responsibility for environmental problems and their sense of moral obligation and leads to the activation of their personal norms [88]. According to the NAM, these persons are then more likely to engage in environmental behaviours [215]. Conversely, individuals neutralize the impact of personal norms when they deny the seriousness of the consequences of their actions and therefore do not even intend to perform or not perform a behaviour [171].

Personal norms are different from social norms because they are anchored in the self and not in a social group [171]. Yet, personal norms can be considered as internalized social norms and communicating social norms can stimulate the internalization of personal norms [215].

### 2.2.5. Beliefs

The New Environmental Paradigm (NEP) and the Human Exception Paradigm (HEP) characterize two different sets of beliefs [149], [219]. The New Environmental Paradigm is a belief that human activity and a fragile biosphere are interconnected elements [113]. It highlights the importance of respecting "natural limits" and of preserving the "balanced integrity of nature" [149], [176], [219]. Conversely, the "Human Exception Paradigm" is a belief that human beings are above nature and can consume whatever resource they want without caring for the environment [64], [219]. According to this utilitarian belief, water is a priceless human right and

an unlimited resource that can be used by humans without restrictions to help them maintain a basic wellbeing [11], [148].

The NEP-HEP also refers to a scale assessing environmental attitudes [64], [148], [219]. More particularly, it was used by [136] to evaluate the impact of general environmental beliefs on specific water beliefs and on predicting water consumption [148]. Using a Likert Scale from 'Strongly Agree' to 'Strongly Disagree', individuals were asked to rank a number of assertions such as 'Humankind was created to rule out over the rest of nature' or 'Drinkable water will exhaust very soon if we do not save it' [148], [219]. General environmental beliefs were found to be weak predictors of water consumption behaviours but appeared to influence specific ecological water beliefs [148]. In turn, these specific beliefs seemed to directly impact water consumption behaviours [148], [219]. As an example, general HEP beliefs appeared to limit the expression of specific water ecological beliefs and to hinder water conservation activities [148]. Conversely, believing that water is a resource that needs to be preserved encouraged water conservation [148].

The NEP beliefs form part of the Value Belief Norm Theory of Environmentalism along with Schwartz' Value Theory, the Norm Activation Model and the NEP [113]. More specifically, this theory adds an environmental focus to the NAM [113]. Personal norms are direct determinants of pro-environmental behaviours in this model. However, in addition to the awareness of consequences for valued objects and the ascription of responsibility to take action, they are also influenced and activated by values and NEP beliefs [113], [176].

### 2.2.6. Economic Reasoning

The Rational Choice Theory is an economic theory used to explain human behaviours [220], [221]. According to this theory, people's actions are justified by short-term personal benefits [171]. Prior to deciding to take or not to take action, individuals estimate the costs and benefits of such action [220]–[222]. They then choose the option that will bring them the greatest satisfaction [221]. In terms of environmental actions, people need to receive enough information about the environmental costs and benefits of their actions to make well-informed decisions [120]. Following this theory, potential motivators of environmental action include the desire to save money or to avoid punishments [113], [206], [214].

Moreover, according to the Prospect Theory, people are more willing to act to prevent losses than to obtain gains [179], [223]. Informing them about losses that can be avoided is thus more effective than mentioning potential gains [179], [223].

### 2.2.7. Knowledge

Based on the Theory of Planned Behaviour, [224] developed the Model of Responsible Environmental Behaviour. This model acknowledges the influence of environmental knowledge on intentions and affirms that intentions are influenced by individuals' knowledge of environmental issues and of relevant action strategies [224], [225].

Yet, the Information Deficit Model or Deficit Model assumes that there is a deficit or gap in public knowledge of environmental issues that must be filled by expert knowledge [226]–[229]. In this context, a lack of knowledge, leading to a lack of understanding, hinders behaviour change and public involvement in pro-environmental behaviours [130], [228], [230]. Similarly, a lack of knowledge and information about their own resource consumption lead people to develop misconceptions [39], [63], [127], [231]. Regarding water usage, invisible pipes and flows can make it difficult to correctly estimate the amount of water provided to an household [39]. Thus, individuals do not always realize the amount of water they use on a daily basis [63]. General ideas and prejudices lead them to wrongly evaluate their own consumption [63], [127]. For instance, daily activities, such as clothes washing, showering and tap use, are usually incorrectly estimated [127]. Moreover, individuals who consider themselves as high water users tend to use less water than self-nominated medium or low water users [63], [127].

However, increasing knowledge and awareness alone does not always lead to pro-environmental behaviours [130], [170], [226], [228], [230], [232]–[235]. It can even be counterproductive and lead to increased water consumption over time in reactance [186], [236]. Moreover, according to the Knowledge-Action Gap, despite knowing about environmental issues, individuals do not also act accordingly due to external barriers [187], [230]. It is therefore crucial to ensure that their environmental actions are made possible [187], [230].

### 2.2.8. Identity

One criticism that has been formulated against attitude-based theories explaining behaviours is that it fails to take into consideration people's identities [237]. Yet, various theories have demonstrated the impact of identity on behaviours. All of which are applicable to environmental behaviours and can be used to promote sustainable actions. These theories show that people's actions can be motivated by their will to be in harmony with the way they -and others- see themselves, by a desire to feel complete or by their social environment and their willingness to fit in a social group and obtain social validation of their identity.

Identity can be defined as "a set of meanings attached to the self that serves as a standard or reference that guides behaviour in situations" (Stets et al., 2003). It is influenced by values that

represent what is important for individuals in their life, how they see and want to themselves and the kind of person they want to be [195].

Thus, values affect environmental judgements, intentions and behaviour via their effect on self-identity [195]. Having a sense of identity indeed leads people to make behavioural choices that are consistent with the way they see themselves [176], [177]. Self-identity can be described as "the label used to describe oneself" and includes personal motivations and social interaction driving people's actions according to their own and others' expectations [187], [195]. Self-identity incorporates "all the roles owned by an individual that affect action and behaviour, which may precede and contribute to expectations and norms" [177]. Contrary to values that remain abstract and stable over time, self-identity can change easily [195].

Environmental self-identity means that individuals sees themselves as environmentally-friendly person [88], [195]. Biospheric values can be considered as the "stable core" of environmental self-identity [195]. However, even though they have biospheric values, some people might not consider themselves as eco-friendly persons if some parts of their behaviour go against these values [187], [195]. People with a strong pro-environmental self-identity are more likely to act in a pro-environmental way and to perform pro-environmental behaviours to be in line with their identity [195], [176], [187]. More specifically, behaviour specific self-identity has been found to be linked with specific behaviours while general environmental self-identity can predict a range of environmental behaviours [187], [195]. For instance, individuals who consider themselves as persons who recycle are likely to recycle [195]. Individuals who consider themselves as eco-friendly persons are likely to perform a variety of environmental actions [187], [195]. However, behaviour specific self-identity has a stronger influence than general environmental self-identity on behaviour intentions [187]. Moreover, it explains the persistence in performing certain behaviours whereas general environmental self-identity justifies spill-over effects between different environmental behaviours [187], [195], [238], [239]. For instance, general green identity is linked to specific behaviours related to domestic water and energy conservation but can also lead to waste reduction activities or eco-shopping [187], [195]. This is in line with the idea of "catalyst behaviours" or the belief that adopting an environmental behaviour might lead to the adoption of other behaviours that are beneficial to the environment [187].

#### 2.2.8.1. The Cognitive Dissonance Theory and The Self-Discrepancy Theory

Following this idea of consistency**,** the Cognitive Dissonance Theory assumes that individuals strive for consistency within themselves [240], [241]. Facing internal dissonance due to conflicting values or attitudes can result in psychological discomfort for individuals [241]. For instance, people who consider themselves as environmental activists feel a discomfort when not

taking part in environmental activism [183]. This psychological discomfort leads them to either act to minimize this dissonant state or to prevent the increase of such dissonance by avoiding certain situation [240], [241]. In line with this, the Lewinian principle states that individuals who commit to a certain identity goal act toward the attainment of that goal to compensate a sense of incompleteness [211], [242].

Applied to environmental behaviours, the Cognitive Dissonance Theory suggests that people who think of themselves as green avoid performing actions that are in contradiction with their perceived self-identity [187], [243]. More particularly, [244] demonstrated that dissonance could increase water conservation. In their study, participants were informed of their wasteful water habits and asked to sign their name on a flyer saying "Please conserve water. Take shorter showers. Turn showers off while soaping up. IF I CAN DO IT, SO CAN YOU!" [244]. These participants experienced dissonance at different levels and changed their water usage [244]. This strategy can however have a reverse effect [187]. An important gap between a desirable behaviour and a pro-environmental behaviour can lead people to change their attitudes towards the environment instead of changing their lifestyles.

In the same line, the self-discrepancy theory suggests that one person can have multiple selves and can feel multiple internal discrepancies [16], [245], [246]. These 'selves' are the actual self, the ideal self and the ought self [16], [245], [246]. All of which can be perceived from one's own perspective or from one's perception of how others perceive them [16], [245], [246]. Perceiving a gap between two selves motivates people to act to reduce feelings of discomfort, dissatisfaction or disappointment [16], [245], [246]. For instance, discrepancies between the way people see themselves (own actual self) and how they would like to be (own ideal self) or how they believe others think they ought to be (other ought self) motivate action [16], [245], [246].

#### 2.2.8.2. The Symbolic Self-Completion Theory

The Symbolic Self-Completion Theory assumes that people are born incomplete "without a fully-formed concept of self" [16], [247], [248]. Individuals therefore aim at having a complete self-definition [247]. When they introduce themselves to others, for instance as eco-friendly persons, it is assumed that they have the attributes of an eco-friendly person [247]. However, when they lack these qualifications and thus feel incomplete, people tend to develop self-symbolizing behaviours and engage in activities that act as identity symbols to show themselves and others that they possesses this identity [211], [242], [247]. For instance, informing individuals who wish to be 'green' that their shopping choices are not sustainable motivate them to recycle more often [211]. However, individuals who feel a sense of "identity-goal completeness" moderate their identity-goal efforts [211], [247]. Indeed, people striving to 'be

green' decreases their recycling actions after being told that their shopping choices are environmentally-friendly [211]. Likewise, acquiring a symbol of green lifestyles, such as buying green products, also reduces the performance of other types of environmental behaviours, e.g. recycling. [211]. In line with this, the Self-Perception Theory explains that reminding people of positive past actions or changing the perception of their past behaviours can influence their environmental self-identity and therefore promote environmental actions [195].

### 2.2.9. Social Environment

Social influence is a term used "when an individual's thoughts, feelings and actions are influenced by other people or groups" [249]. According to the Social Cognitive Theory (SCT), derived from the Social Learning Theory (SLT), human agency is widely influence by social contexts and human behaviours are embedded in social systems [250], [251], [252]. In line with this, the Other Person Principle states that people believe they are not influenced by others when in fact they are [253], [254]. Individuals acquire new behaviours by observing others' behaviours, especially the behaviours of people who are like them or with whom they "feel a sense of shared identity" [179], [251], [252]. Other people observing this process, such as parents observing the behaviour of their child, can either reinforce the behaviour or punish it [251], [252]. Reinforcement will encourage individuals to perform the behaviour again while punishment will prevent them from doing so [251], [252]. To encourage repetitive behaviours, it is important for learners to believe they have the abilities to perform a behaviour, to receive a positive response after performing the behaviour and to perform the behaviour in a good setting and environment [255], [256].

More generally, according to the Identity Theory, society indirectly influences social behaviour by influencing individuals' identities [257]. The self reflects society and people have as many identities as the "group of persons with which they interact" [258], [257], [237]. Similarly, the Social Identity Theory refers to individuals' perception of themselves as group members [259], [260]. It assumes that individuals try to maintain a positive social identity to enhance their self-esteem [261]. This positive identity is developed by positive comparisons "between the ingroup and relevant outgroup" [261]. In that sense, group identification and membership can also influence behavioural intentions [183]. By performing eco-friendly actions, people can express their personal identity "I am a green and act pro-environmentally" as well as their social identity "I am part of the group that is concerned about the environment" [176]. However, when they are not satisfied by their identity, individuals can decide to leave the group or try to attain a more positive identity [261]. To reinforce this identity, the Self-Perception Theory suggests to remind people of past actions- and especially that they acted pro-environmentally- or to manipulate the

perception of their past behaviours to influence their environmental self-identity and motivate positive actions [195], [262].

As described in the literature, multiple theories aim at explaining the internal and psychological drivers of environmental behaviours. Most of them refer to similar concepts, such as attitudes, intentions, values, personal and social norms, knowledge and identity. These concepts are not always connected in the same way but all have an effect on behaviour. While it can be difficult to consider all these strategies, the ones reviewed in the section offer insight regarding the influences that should be considered when trying to change behaviours. Moreover, it provides useful guidelines as to the most effective ways to encourage environmental behaviours. Therefore, Chapter 4 of this thesis describes the use of these theories in the context of this research, to promote sustainable water consumption. Another major aspect of this research is the use of ICT as a tool to encourage sustainable behaviours. Thus, the next section presents the theories applicable to the adoption of new technologies.

## 2.3. Theoretical Background on the Adoption of New Technologies

As the adoption of new technologies is widely discussed throughout this thesis, the author considers that it is necessary to review key theories regarding the adoption of these tools, alongside the behavioural theories above-mentioned.

When implementing new technologies, care should be taken to follow the best practice as outlined in the Technology Acceptance Model [263]. According to this theory, the more useful and easy individuals think the technology is, the more they will be willing to use it [263]. Therefore, importance should be placed on the “perceived usefulness” and the “perceived ease-of-use” of a technology for consumers [263]. “Perceived usefulness” is the first factor influencing behavioural intentions to use technology [263], [264]. It refers to "the degree to which a person believes that using a particular system would enhance his or her job performance” [263]. The benefits resulting from the adoption of innovation therefore needs to be personally relevant to individuals for them to take action [176]. On the other hand, “perceived ease of use” is a second determinant and can be described as "the degree to which a person believes that using a particular system would be free of effort" [263], [264].

According to the Diffusion of Innovation Theory, the rate of adoption of an innovation varies depending on the attributes of the innovation [176], [265]. The adoption is also influenced by factors such as (a) the willingness to cope with the inconveniences resulting from the adoption i.e. the willingness to invest in the technology (b) the lack of perceived risks regarding the functionality and economics of the innovation and (c) social pressure [176]. Additionally, that

knowledge about environmental issues can encourage the adoption of eco-friendly innovations [176], [266]. Thus, informing people about the benefits of an innovation on the environment is key to motivate the purchase of new equipment [176].

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This chapter reviewed the socio-demographic and contextual factors traditionally found to influence water-saving and environmental behaviours in Section 2.1. It particularly identified the socio-demographic factors that most impact water conservation in the UK. Determining these factors is crucial to design methods of behaviour change that are tailored to people's characteristics. More specifically, the existence of these factors within the population studied in the context of this project needs to be assessed to inform the behaviour change strategies implemented. Through the overview of these factors, this section will therefore inform the design of preliminary surveys, as described in Chapter 5. Overall, behaviours are also largely influenced by internal and psychological factors. Section 2.2 therefore reviewed a variety of theories aiming at understanding the impact of attitudes, intentions, values, knowledge and identity on behaviours. Reviewing these factors helped determine those that trigger environmental and wasteful habits, and thus those that need to be targeted to encourage more sustainable water-behaviours in a UK-specific context. Finally, the use of ICT is a central element of this research and it was important to identify the psychological factors that would encourage their adoption to efficiently implement them in the context of this project (Section 2.3). Thus, this chapter provided baseline information to better select the methods of behaviour change that should be implemented and evaluated via the user-interface to encourage sustainable water behaviours. This selection forms the theoretical framework of the present project and will be described in Chapter 6. The next chapter will add to this framework by adopting a more practical approach. It will provide examples of methods and strategies that are traditionally implemented to achieve large-scale behaviour change within a population. This includes informational campaigns deployed at regional and national levels and the use of ICT as information tools. While this chapter is theoretical in nature, the next chapter will therefore offer more practical guidelines as to the most efficient ways to implement the selected methods through ICT to promote water conservation.

# Chapter 3: Literature Review Part 2: Promoting Behaviour Change

Persuading people to make long-lasting changes to their behaviour is necessary to efficiently reduce resource consumption [267]. However, the first requirement to achieve behaviour change is to understand people's behaviours [268]. Chapter 2 identified the socio-demographic factors that encourage -or discourage- water consumption. This set of factors will be assessed in Chapter 5 via surveys within the studied population to better understand – and ultimately change - their environmental attitudes and behaviours. Chapter 2 also provided the baseline information that will form the theoretical framework of this research described in Chapter 4, by reviewing behaviour-building and behaviour-changing theories. This review also informs the choice of methods of behaviour change to implement and evaluate via ICT to encourage water conservation. However, to efficiently deploy these methods in the context of this project, it is also crucial to identify the best ways to apply them on a practical level. This chapter will review different types of practical measures that can be implemented on a large-scale to promote behaviour change. It will provide guidelines regarding the type of information that should communicated and the most effective means of communicating this information in order to encourage people to integrate changes into their daily life.'

Structural approaches directly influence behaviours, the availability of products, consumption norms and the socio-technical context in which decisions are made [112], [164], [173]. They can also force a change in people's lives by (a) making environmental behaviours cheaper and more convenient and (b) making wasting behaviours more costly, less convenient or unlawful [243]. [164]. Conversely, voluntarist or psychological approaches aim to encourage ecological behaviours through longer-lasting attitude changes by targeting the source of the problem [269]. Section 3.1. thus focuses on informational campaigns and suggests guidelines to efficiently implement them. However, the impact of these measures on individuals is sometimes limited [130], [186], [270]–[272]. By following principles of social marketing, Community Based Social Marketing (CBSM) methods are therefore useful to overcome the problems encountered by traditional informational campaigns and to induce behaviour change [269], [271], [273]. In addition, changing people's routine also requires the introduction of new technologies [31], [274]. Section 3.2 focuses on the use of ICT as a way to deploy both structural and voluntary approaches to better achieve behaviour change. On the one hand, structural changes are needed to democratize the use of these ICT on a larger scale [269], [275], [276]. On the other hand, a wider use of these technologies would allow the implementation of voluntary strategies promoting long-term behaviour change, such as near real-time feedback and goal setting [269], [277], [278].

## 3.1. Psychological & Voluntary Strategies and Approaches

Voluntary approaches assume that individuals are 'relatively independent from the structures that inform them' [279]. They therefore focus on changing people's attitudes, beliefs or preferences [173], [276], [279]. Section 3.1.1 offers guidelines to efficiently inform individuals and to ensure that they act upon the information they receive. The importance of credible and trustworthy information sources is first mentioned [179], [280]. Since tailored information has more impact on people, it is suggested that the type of information provided should be adapted to the audience targeted [88], [179], [188]. Current informational initiatives undertaken by UK water companies are then discussed. Finally, Section 3.1.2 recommends the use of CBSM to improve current initiatives and their impact on the public.

### 3.1.1. Informational Campaigns

Information is a source of knowledge and, as such, a 'prerequisite for many behaviours' [220]. Yet, the Information Deficit Theory suggests that there is a gap in public's knowledge of environmental issues [226]–[229]. As people make a systematic use of the information they receive, information is a key element of the decision process and of individuals' involvement in environmental actions [130], [167], [168], [175], [177], [179]. By emphasizing the implication of individuals' behaviour in causing a problem, information leads people to start questioning their habits [175], [208]. That is why educated people who are aware of water issues tend to conserve water more regularly than other persons [64]. Information about the potential impact of behaviour change on resource consumption also encourages sustainable behaviours by giving individuals a sense of control over their behaviours [175]. It is however crucial to provide the public with consistent and sufficient information [176], [179]. Therefore, the information provided should come from reliable sources (Section 3.1.1.1.) and be tailored to individuals (Section 3.1.1.2) [179], [187], [195], [280].

#### 3.1.1.1. The Importance of Information Sources

Individuals behave in an environmentally responsible way depending on the information they receive about the urgency of a problem and the necessary strategies to resolve them [179]. Technical analysis of environmental issues often reflect complexity and uncertainty [130], [179]. It improves the intellectual understanding of problems but does not rely on any emotional involvement [130], [179]. As environmentally responsible behaviour requires easily understandable information, it is important to facilitate the understanding of technical information [130], [179], [281]. Obviously, the information provided should also be accurate to prevent the development of incorrect ideas [176].

Additionally, the perceived credibility of the information either motivate or discourage people's actions [179], [280]. Doubts regarding the trustworthiness or the competency of the source of a message particularly disengage people and make them sceptical [283]. Paradoxically, individuals tend to give more credibility to their peers than to officials [179]. Likewise, media, celebrities, role models and individuals with central positions in social networks have an increased power in conveying messages [179], [282]. Media are a major source of information regarding environmental issues [282], [283]. Yet, they usually cover many differing viewpoints and tend to focus on dramatic and immediate dangers [179]. This can be counterproductive and lead people to develop unpleasant sentiments such a sense of futility and a feeling of "global helplessness" when faced with these overwhelming environmental issues [150], [179], [284]. To correct this failing, it is important to inform about the options available to solve the problem and their consequences and to show the impact of small actions on the environment [175], [284]**.** This information will help to efficiently provide information to participants to this study in order to encourage a change in their behaviours (see Chapter 6).

#### 3.1.1.2. Providing Tailored Information

Due to the influence of one's identity on behaviours, information that targets some aspects of identity can better promote environmental behaviours [187], [195]. Information either motivates or prevents actions depending on whether or not it relates to people's values and self-image [179], [280]. Environmental information has little impact on consumers when 'protecting the environment' is not an important personal value for them [88], [179]. However, priming a general value with information can promote behaviour change [179], [188]. For instance, environmental benefits should be highlighted when people value the environment whereas costs savings should be mentioned when people are concerned with financial matters [164]. In the context of this research project, tailored information will be provided to participants to ensure that the messages sent are well-received (see Chapter 6).

Conversely, information that goes against their beliefs lead people to develop an emotional response preventing pro-environmental actions [130]. For instance, the safety of using alternative water sources, especially recycled water, is still questioned by many individuals [7], [287]–[290]. Due to a lack of information, individuals believe that using these sources could engender health issues [287], [289], [290]. Thus, they are often reluctant and sometimes feel disgusted by the idea of using recycled water for drinking or showering purposes [291]–[293]. This is problematic as these practices have the potential to lower the water demand [292]. To counter these prejudices and increase the acceptance of these practices, education and information about the safety of these alternatives sources should be conveyed [291], [294].

#### 3.1.1.3. Campaigns Conducted by UK Water Companies

Water companies have a role to play in informing consumers about the importance of sustainable water usage [41]. Creating water-efficient messages and testing their impact is necessary to determine the best way to promote efficient behaviour [41]. Thus, in the past few years, various informational campaigns promoting conservation have been launched either individually or collectively by water companies, i.e. the 2009 Shower Power campaign was conducted conjointly by several companies [105]. The 'Love Every Drop' strategy initiated by Anglian Water in 2010 includes a set of different campaigns such as the "Drop 20" campaign that aims at giving individuals tips to progressively reduce their daily water usage [295], [296]. Likewise, due to frequent disturbances in their sewage treatment process, Wessex Water also launched the educative "Don't flush it, bin it" campaign to encourage people to be more careful about the products they throw in their toilets through tips and advice [297].

However, interactions between water companies and consumers in the UK are still limited. They usually consist of gathering information about consumers' water consumption for companies, and initiating contact to pay the bills, make enquiries or to seek assistance for consumers [298]. The means of communication used to interact with customers also remain basic i.e. phone calls, mails and emails, websites [299]–[302].

While informing and educating individuals about environmental issues is necessary, the sole provision of information to eliminate the knowledge deficit (Section 2.2.7) does not always lead to more conservation or to long-lasting behaviour change [130], [186], [270]–[272]. Informational campaigns are not considered as sufficient on their own to promote environmental actions that are costly in terms of money and time and that prevent people from doing what they like [243], [303]. This following section therefore advocates the use of prompts based on social marketing methods to improve the efficiency of such methods [164], [304], [305]. As it will be explained in Chapter 6, these elements will be considered by the author to design efficient methods of behaviour change as part of this research project.

### 3.1.2. Community-Based Social Marketing

Campaigns developed in the past few years in the UK to encourage water-savings were mainly large-scaled ones based on education and advertising [105]. While these campaigns increase users' awareness, they do not seem to concretely change individuals' behaviours [271], [273]. This limited efficiency led Community-Based Social Marketing (CBSM) to be considered as an alternative way to promote sustainability [253], [271]. CBSM is influenced by research in the social sciences and in social psychology and by marketing techniques [271]. Tt can transcend the

gap between knowledge and action, as described in the Knowledge-Action Gap Theory, and induce effective changes in the behaviour of the targeted audience [187], [230], [273]. Indeed, by setting goals, developing a sense of community and inspiring concern for the environment, these techniques are powerful motivators of behaviour change [273]. Tools used range from monetary incentives, prompts to remind people to engage in certain activities or the provision of normative information about water conservation [306].

Social marketing campaigns to reduce consumption for environmental purposes is rare compared to other types of campaigns [307]. However, they have been used to target a variety of conservation behaviours [308]. Concerning water consumption, community-based social marketing is a good solution to "identify and break water consumption habits", as demonstrated by various studies [272], [306], [309]. In the US, the Ecoteams program resulted in a reduction of 25–34% for water consumption across different US cities [307], [310]. In Thornton, USA, 46% of the identified "high water use" residents taking part in the CSBM campaign decreased their water use [311]. In Canada, mechanisms of CBSM used to support regulation in Kamloops, British Columbia led to a 15% reduction in water consumption [309].

In areas affected by water-scarcity, these methods have been implemented in conjunction with the deployment of ICT. In the Dubuque Water Portal study, access to an online portal informing users of their consumption, coupled with training classes and special events resulted in a 6.6% reduction in participants' water use at the end of the 9-week pilot [181]. Similarly, in Perth, Australia, the implementation of smart meters and dashboards, along with CBSM methods led to water savings of about 9.9% per year [273]. This is particularly useful in the context of this research and provides useful guidelines regarding the implementation of ICT in this project. These recommendations are detailed in the following section.

While their efficiency has been proven by these studies, CBSM campaigns need to be supported by structural changes to better change behaviours [269]. Implementing voluntary approaches in conjunction with structural changes can improve their efficiency while structural strategies can also benefit from informational campaigns to increase public acceptance of such changes [164], [243]. Converting effective behaviour change strategies, such as the CBSM, into governance also facilitates the education of society at large [112]. However, as described in the introduction, the UK has not yet implemented the structural changes needed to use such methods. While the retrofitting of water-saving devices is proposed by some water companies, the implementation of smart water meters and pricing policies is not a governmental priority presently. Yet, from a theoretical perspective, it is also crucial to implement structural changes to reduce external

barriers that limit individuals' environmental actions, despite their knowledge of environmental issues and pro-environmental values (Sections 2.2.3 and 2.2.7) [187], [230], [312]. Moreover, people adapt their behaviours to long-lasting structural changes and these changes eventually guide their actions more than their own willingness or motivation [243]. They can also lessen the feelings of frustration, caused by the lack of social and political support, that hinder engagement in environmental actions [38], [270].

However, while solutions to water issues have to be achieved through a "large-scale regulatory and infrastructural action", individual effort within households is also necessary [104]. Combining regulation, efficiency appliances and behaviour change is therefore the most promising strategy to reduce residential water demand [306], [313]. To do so, the author believes that water management in the UK can integrate the advantages of the latest technologies to encourage behaviour change. These technologies facilitate the collection of data about consumer usage, ease the interaction between consumers and companies and gives individuals the possibility to control and regulate their consumption by easily accessing information about their water usage [104]. They are therefore useful tools to communicate information to encourage water savings in the context of this research project.

## 3.2. Information and Communications Technologies to Promote Behaviour Change

The use of ICT is a good example of the necessity of combining structural and voluntary approaches to achieve both structural and psychological changes in the water sector [292]. During the last few years, computing technologies have started to be perceived as a "driving force towards lifestyle management and behavioural change"[254]. They help counteract the current lack of temporal and spatial details about water usage caused by the limited capacities of traditional water meters [314]. Indeed, high-quality information about users' behaviours can be easily obtained through the use of tools that provide accurate and near real time data [314]. This high-quality data makes it possible to detect habits and behaviours that cannot be detected by simple water meter readings and helps evaluating the effectiveness of water demand management methods [268], [314]. It also enables companies to understand the way water is used and the areas in which changes are needed [268], [315]. That way, it gives indications as to the needs and gaps regarding current water management and helps to implement adequate conservation strategies [316]. The author believes that using these technologies as a tool to encourage behaviour change among participants in the context of this study can efficiently lead to increased water conservation.

### 3.2.1. Encouraging Behaviour Change through Feedback

Feedback is defined as "*information about the results of a process, experiment etc; a response*" [317]. Feedback about water consumption informs individuals about their water usage. It helps fill the knowledge deficit (Section 2.2.7) and allows them to make "better informed choices" [231], [270], [318], [319], [320]. The information must be easy to understand and be provided by trusted and reliable sources [108], [254], [321]. Information that is not immediately plausible can indeed lead people to question the entire system and make them lose their trust in the monitoring of their usage [322].

The efficiency of feedback sometimes varies depending on individuals' socio-demographic characteristics and on external factors [108]. As an example, concerning energy, people with higher levels of education, higher income and higher electricity usage tend to achieve greater reductions when receiving feedback [108]. Climate can also influence the effectiveness of feedback, which is why it is interesting to study their impact in the UK [104], [108]. Feedback has been found to have more impact on individuals living in more temperate climate than those living in countries affected by extreme climates, where it is hot in summer and cold in winter [108]. However, studies found that, overall, feedback increases people's understanding and awareness of their own consumption [173], [270], [318], [323]. It also gives them a sense of individual control over their environmental actions [104], [177], [273]. For this reason, feedback is often appreciated by individuals [273]. Moreover, feedback (a) impacts habitual and repetitive behaviour, (b) influences appliance purchasing decisions and (c) leads to behavioural adjustment [39], [108], [164], [322]. It encourages more sustainable behaviours and water and energy savings [61], [104], [108], [173], [181], [270], [317], [318], [322]–[327]. To efficiently reduce people's consumption, the literature on the subject however recommends that guidelines should be followed regarding (a) the nature of the feedback, (b) the frequency at which it is sent and (c) the content and focus of the feedback.

#### 3.2.1.1. Nature of the Feedback

##### Positive Versus Negative Feedback

Positive and encouraging feedback engender behaviour change [188], [211], [328]. According to the Lewinian principle (Section 2.2.8), individuals who commit to a certain identity goal act toward the attainment of that goal to compensate a sense of incompleteness [211], [242]. Positive feedback therefore improves behaviour by emphasising the feasibility of reaching a given identity goal and of succeeding in achieving a specific task [211]. It encourages sustainable actions from people striving to be eco-friendly. In line with the Social Learning Theory, injunctive

and encouraging messages encourage people to maintain that behaviour in case of good behaviour [256], [329]. Thus, a shift has to be made, from guilt-inducing messages to positive and encouraging communications [328].

However, positive feedback can also have drawbacks. Feedback informing people that they are environmental friendly persons lead people to see themselves as environmental-friendly persons [195]. As stated in the Self-completion Theory (Section 2.2.8), it induces "a state of identity goal completeness" which can discourage further actions [211]. Conversely, receiving negative feedback induced a "state of incompleteness" that encourages people to take more actions to be in accordance with their perceived self-identity [211]. For this reason, negative feedback has also been found to positively impact people's actions [211], [330], [331]. Similarly, messages referring to an idea of loss have more impact than those insisting on potential gains [329] Therefore, when sending feedbacks, it is also important to let people know what they might lose if they are not careful about their consumption [329].

#### Tailored feedback

As seen in Section 3.1.1.2, personalised information impacts individuals' consumption [104]. Feedback that is tailored to individuals, household members or households groups particularly increases people's awareness and understanding of their water use and encourages the adoption of "future conservation behaviours" [91], [108], [332], [333]. By receiving feedback after they perform specific actions, people are able to visualize how much water is used, when and in which rooms of the house [61], [90], [334], [335]. It allows them to identify the "normal baseline" of their consumption and reinforce learning processes [270], [322]. Feedback can also be tailored to individuals' current behaviour, level of motivation and interests and suggests personalised actions and water-saving targets [164], [254].

### 3.2.1.2. Frequency

Feedback can be provided directly and indirectly [108]. Indirect feedback includes raw data that has been processed by utility before being sent to customers in the form of detailed bills [108], [317], [336]. Conversely, direct or real-time feedback is immediate and is received from a meter and through user interfaces [108], [317]. Feedback provided over a long period of time participates in the formation of new habits while feedback provided on a short term leads to less efficient systems [108], [175], [337]. A continuous or frequent access to feedback particularly encourages people to conserve water on a regular basis [104], [338]. The faster they receive feedbacks, the more they tend to reduce their water consumption [104]. That means that effective feedback should be given daily or more [108], [175], [317], [333]. Inadvertent feedback sent

occasionally and at specific moments i.e. when moving into a new house, also shows promise in encouraging savings [317]. Similarly, simply letting consumers choose how often they want to access their data leads them to reduce their consumption [104].

#### 3.2.1.3. Focus of the Feedback

While feedback is a good way to provide information, it is people's choice and responsibility to act according to the information they receive [270]. Motivation to conserve is a pre-condition for feedback to efficiently work [175]. Informing people about their consumption does not have any impact if they are not motivated to save water at first [175].

In order to increase their motivation to conserve and to reach groups of consumers with differing interests, it is therefore important to combine diverse motivators [175], [318]. In the context of this research, five types of motivators have been reviewed: (a) financial instruments, (b) environmental instruments, (c) social instruments, (d) tips and advice and (d) goal setting.

##### Financial Focus

Saving resources is influenced by environmental awareness but also by general money-saving attitudes [318]. The Rational Choice Theory (Section 2.2.7) states that people need to receive enough information to estimate the costs and benefits of their acts before taking action [120], [220]–[222]. Following this theory and the Prospect Theory (Section 2.2.7), the desire to save money and to avoid financial losses and punishments motivates environmental action [113], [206], [214]. For [340], people are more likely to reduce their consumption when receiving monetary rewards from sponsors or utilities in the form of (a) direct payments or (b) financial savings resulting from conservation efforts or peak demand reduction [340]. Moreover, informing people that they are losing opportunities to save money by not saving resources can also persuade them to act [179]. Thus, feedback linking environmental advantages and economic benefits or used in conjunction with water pricing policies increases conservation by making people aware of the costs of their consumption [268], [254], [270], [284].

Yet, showing costs can change people's focus from an environmental aspect to a financial aspect and decrease their interest in conservation [318]. For instance, to fit variable price tariffs, individuals tend to be more careful about the times at which they are using water than about the amount of water they are using [104]. It is therefore necessary to refocus the purpose of the feedback on environmental causes by providing environmental information [104].

### Environmental Focus

As discussed in Section 3.1.1. informing individuals about the consequences of their behaviour on the environment leads them to start questioning their habits but also gives them a sense of control over their behaviours [175], [208]. By showing people the impact of their consumption, water feedback combined with information about water issues motivates water savings [64], [323]. For instance, it can provide comparisons between households' consumption in terms of their average environmental impact [318]. In addition, using analogies for the amount of water used, such as referring to the number of bath tubs or buckets of water used by a household for specific activities, also helps individuals visualize their consumption [340].

### Water-Energy Feedback

Water and energy consumption are often associated because of their similarity and their interdependence [341]. Water is necessary to generate and distribute electricity and pumping, transporting, treating and distributing water requires energy [342]. When implementing water conservation measures, it is important to inform people of the link between energy and water. Lack of information about this link could indeed result in more efficiency in one sector but in increasing demand in the other [342]. Conversely, promoting efforts in one of those sectors could also generate positive results for the other sector [342].

Water-energy feedback seems to encourage an important decrease in water consumption because it reaches people who have an interest in water conservation as well as those interesting in energy saving [323]. In their study, [86] found that the group receiving water-energy feedback reduced its consumption more than the groups receiving water-only feedback or no feedback at all [86]. More generally, when receiving information about their consumption, individuals appreciate receiving a hot and cold water breakdown to be able to link their hot water consumption to their energy consumption [90].

Due to energy being invisible and abstract, consumption usually occurs through everyday activities such as cooking and washing, and directly and indirectly through the use of appliances [175], [270], [317]. By making energy consumption more visible through water-using activities, feedback can also act as an "eye-opener" [270].

### Virtual Water

Virtual Water is "the water used in the production process of an agricultural or industrial product" [343]–[345]. For instance, producing one kilogram of grains requires the use of nearly two thousands kilograms of water [345]. It is linked to the 'water footprint' which describes 'the

volume of water needed for the production of the goods and services consumed by the inhabitants of the country' [346].

Currently, in the UK, 2400 litres of water per person per day are needed for the production of food for consumption [347]. Informing consumers about their water footprint can encourage them to make efforts to reduce (a) their direct water footprint or domestic water usage and (b) their indirect water footprint by making better-informed consumption choices [348], [349]. It is important for people to understand that the largest part of their water footprint is linked to the products they buy [349]. To reduce their indirect water footprint, they can either change some of their life habits i.e. eat less meat, or maintain the same consumption patterns but consume differently [348], [349]. This can be done by buying products such as cotton or coffee that have low water footprint or that are sourced in areas that are not subject to water scarcity [347], [348]. While reducing indirect water footprint does not have a direct impact on domestic water usage, it increases people's awareness of their water consumption and leads them to develop more sustainable habits [350].

### Social Focus

Social normative messages or messages showing "social and reputational aspects of conservation" impact behaviours more than environmental or financial messages and have a longer-lasting impact [104], [108], [173], [208], [329]. Social approaches are also more efficient than information-only methods to encourage water conservation [223], [232]. Informing people about the behaviours of others using normative and social comparisons particularly improves feedback efficiency and promotes behaviour change [88], [90], [104], [175], [318], [340]. In fact, in a 2004 report, the UK government insist that behaviour change can be achieved through the gradual change of social norms by modifying the behaviour of people surrounding individuals, such as their peers and family [351].

In line with the Social Cognitive Theory and the Social Learning Theory (Section 2.2.9), behaviour science indeed demonstrates that people tend to conserve more when confronted to the sustainable attitudes of their peers [88], [250]–[252], [329]. Comparisons, especially with similar individuals and households, show that others (a) consider the targeted behaviour as appropriate and normal and (b) are themselves acting accordingly [179], [256]. Applied to water usage, it leads individuals to feel pressure or expectations from their community to reduce their consumption [269]. This either generates cooperation or competition [340]. At the household level, especially within families, exchanges between individuals promote collective efforts to control the household's consumption and develop a common understanding of the household's

usage [322], [156], [339], [352]. Conversely, comparisons can also generates feelings of competition [104], [108], [284], [353], [354]. In the energy domain, this competitive aspect is sometimes the first factor motivating energy savings [355].

However, comparisons are not always appreciated and can prevent people from taking action [339]. Displaying "per occupant" data can make people feel like their privacy is being violated [318]. While comparisons between occupants ensure that individuals are held accountable for their usage, reporting latent domestic habits through eco-feedback can affect the social dynamics of the household and pit family members against one another [90], [339], [353]. It is therefore important to ensure that comparisons do not lead household members to blame one another for their water consumption [90]. Another important drawback of comparisons is that it sometimes leads to increased water consumption [90], [108]. For instance, informing people of their neighbours' usage lowers high energy consumption but increases low energy consumption [330]. Individuals who use less energy think that they are already doing enough efforts and that there is no more need for them to reduce their consumption [318]. In line with the Social Learning Theory, sending injunctive encouragement messages or messages indicating approval or disapproval of one's consumption can help counter this "boomerang effect" [108], [330].

### Tips and Advice

Individuals can be willing to act in a sustainable way but might not know how to proceed [303]. Providing them with tips and advice on how to perform daily water-saving activities can ease their conservation efforts [39], [164], [175], [270], [340]. It also challenges what they considered as normal or "non-negotiable" practices [39], [164], [175], [270], [340]. Discretionary water uses, such as pool use, are considered as negotiable by individuals and can be altered, whereas non-discretionary activities, such as toilets flushing or showers, are often non-negotiable [44], [64], [90], [210].

However, feedback targeting habits that individuals can hardly change or do not want to change has a limited impact [39], [108], [318]. People think more in terms of practices and of the values they associate with these practices than in terms of water usage [356]. Thus, they tend to discard this kind of feedback even though the activities targeted are water consuming [39], [108], [318]. It is therefore important to identify these practices and to provide tips and advice accordingly [39], [90], [104], [108], [329], [356]. Overall, tips should encourage actions that are modest, inexpensive and easy to achieve [179], [164]. People are more likely to undertake important changes if they first agree to small changes [179].

To efficiently encourage behaviour change, feedback about individuals' consumption should include different types of information [175]. In this section, financial, environmental and social instruments have been reviewed along with tips and advice and information about virtual water and energy consumption. While these instruments influence people's consumption, studies have found that the effects of feedback are only visible in an initial period and fades away with time [104], [270]. Thus, the next section discusses the integration of feedback into individuals' everyday life using smart meters and user interfaces. This can encourage continuous savings by allowing people to make long term adjustments in their daily habits [270], [337], [353].

### 3.2.2. Communicating Feedback Efficiently through ICT

Studies conducted in countries affected by water scarcity proved that communicating feedback using ICT can promote water conservation [55], [57], [91], [357]. Yet, the impact of feedback strategies in reducing consumption in places that do not experience water scarcity is currently unclear [104]. Despite being mainly conducted in Australia and the USA, most of the methods used in these studies are not context-specific and can be generalized [55], [57], [91], [357]. They provide guidelines about the implementation of behavioural strategies through the use of new technologies that can be followed in the UK to encourage domestic water savings. Learning from the UK energy sector, that is currently more advanced in terms of technologies, is also beneficial. Applying some of the practices traditionally used by energy suppliers to encourage energy savings can help to promote water conservation in the water sector.

When it comes to domestic water consumption, invisible pipes and flows lead individuals to forget about the way water is provided to them [39]. Within households, informing people is therefore crucial to increase their awareness of their water usage [358]. Traditionally, water feedback is sent by post in the form of bills and paper-based mails. While detailed bills are appreciated by people, providing mail-based feedback has mixed effects on water conservation [104], [359]–[362]. It can lead to a significant decrease in consumption just as it can have no effect on water conservation [104], [359], [360]. Emails have the advantage of providing feedback in an efficient and less wasteful way compared to paper-based feedbacks [108]. When sent on a daily or weekly basis, they are also a good way to constantly re-engage participants in water saving activities [273]. Web pages are also a good way to inform people about the long-term impact of their consumption, although people now prefer direct displays [181], [273], [361], [362].

Feedback sent through the use of in-home displays connected to smart meters improves water management and generates a two-way communication [363]. On the one hand, it actively involves users in the management of their water consumption, contrary to traditional water meters that

are connected only to providers and leave water management "outside the household" [39]. On the other hand, obtaining detailed information about individuals' water usage improves water management by (a) allowing the forecasting of future water demand with a higher accuracy to better adjust water supply networks to usage patterns, (b) enabling informed decision making and (c) improving the design of conservation measures and evaluating their effectiveness [51], [55], [89], [91], [106], [268], [363]–[368].

#### 3.2.2.1. Smart Meters

A water smart meter can be defined as "*an electronic device designed to record water consumption for the utility company and the user" "in real time or near real time*" [104]. It is an informative tool that allows the collection and the communication of up-to-date water usage readings on a real-time or near real time basis depending on the device [55], [104], [273], [369]. It provides households with an overview of their water use, timely feedback and evidence of performance improvements [273].

Smart water meters are particularly useful to collect disaggregated water data. While research is still ongoing to implement such methods, studies show that collecting such data can improve water management [57], [60], [64], [91], [365], [367], [370]. It can help water suppliers to understand people's daily habits to offer tailored water services and initiatives to encourage water conservation. It facilitates the identification of daily water consumption trends, including the factors influencing peak demand, among users belonging to different socio-demographic groups [51], [55], [366]. More importantly, it makes it possible to target specific groups of users in order to achieve larger water savings [273]. In addition, monitoring consumption is necessary to evaluate and improve the impact of water demand management policies on people's consumption [268]. For instance, information about diurnal patterns of water consumption is a key step in implementing efficient restriction regimes and water tariffs [55]. Without this information, the peak hours of domestic water usage cannot be targeted and reduced.

Collecting disaggregated data is however a complex task that still faces several challenges, including the management of big data, the impact of households' privacy and the necessary development of automatic disaggregation procedures instead of manual processing [60]. In addition, identifying specific water-consuming activities can be limited by the inability of discerning several simultaneous events and by the low flow of external consumption [91], [371]. In order to obtain precise end-use disaggregation and to verify the identification of user behaviours by the flow trace software, the use of smart meters can be coupled with the use of surveys. For instance, in the context of their study, [127] conducted a water audit of household

water use behaviours and asked participants to complete a water use diary in addition to the implementation of a flow trace software within households to verify water-using activities.

#### 3.2.2.2. User Interfaces

To have a greater impact on people's lifestyle, the information provided to users should be integrated socially and cognitively in everyday life through an adaptation of devices into users' daily routines [337], [353]. According to [372], feedback has more impact when it is sent and received at the opportune moment. For instance, the efficiency of a message increases when the person receiving it is in a good mood or is ready to immediately comply with a request [372]. Feedback then acts as cues to certain behaviours [372]. Devices that are inserted in the user's world are more likely to initiate interaction at the right moment [372]. Thus, easily-accessed interfaces available on displays, smartphones, tablets or computers can better integrate information into people's daily life [322].

##### In-home Displays

In-home displays can be described as "*smart-meter connected devices that typically present consumers with real-time (or near real-time) information on water use, cost, and comparisons with others as well as the user's own historical consumption*" [104]. These dashboards allow people to see their current consumption statistics and can be tailored to their needs and water usage levels [51], [254]. In-home displays work as both a way to provide feedbacks to the consumers and to improve the communication between them and their water suppliers [39], [108], [175], [181], [223], [317]. These displays encourage great responses in consumer behaviour [106]. This is particularly true when they are located in highly trafficked areas of the house such as the kitchen, the hallway or the bathrooms [90]. Indeed, when feedback is received close to the source of consumption, people can directly link their actions to the feedback and understand how much water each action requires [61].

##### Applications

The energy sector provides useful examples of applications used as a mean to promote energy savings [373]–[375]. With the development of new technologies, people tend to use more appliances and thus, more energy [375]. However, by providing simple options to automatically disconnect or turn on appliances, smart metering and connected applications facilitates savings and can time-shift demand to reduce peak demand periods [106], [376]. For instance, individuals can use applications to remotely control or program their heating and hot water systems to avoid wasting energy [373]–[375], [377]. Mobile apps are especially appreciated for their ease of use, quick access and alerts [270], [340].

### Design of the Interface and Presentation of the Data

The design of in-home communications must attract and maintain users' interest through various presentational styles and the provision of different types of information [254], [270], [339]. The data presented has to be selected, well designed and visually attractive [108], [337]. Ergonomic aspects of the display are very important as they increase usability [322]. A nice design encourages householders to present the display and its benefits to their peers [322]. Simple, appealing and understandable displays are more efficient than complex or sophisticated displays [108], [175], [317], [333], [337]. While it has to be easy to understand, it should not be too simplistic [337] [108], [175], [317], [378]. Displays can include text, tables or charts [108], [337]. However, graphical presentations such as bar charts presenting historical comparisons or consumption peaks and pie charts showing day and night time consumption are more attractive to consumers than textual presentations [90], [318], [340].

Ambient displays showing interactive screens or moving pictures are usually more efficient than other types of display [340]. [181]. These displays are continuous and "unobtrusive" as they blend in with the environment, keep people informed and do not interrupt or demand action [181]. They do not require users' conscious attention and imply little cognitive effort [88]. For instance, traffic lights feedback showing the different level of consumption positively influence users' behaviour [39]. Similarly, LED displays and sound alarms encourage water savings by alerting householders of abnormal usage and consumption spikes [39], [104], [270], [314], [317]. In the study conducted by [61], LED sticks were implemented in showers, lighting up for every five litres consumed. This system led to a reduction of about ten litres in the participants' average water usage over the course of the study [61]. On another note, visual images can also convey environmental messages better than text [179]. They catch people's attention and can create environmental consciousness by leading individuals to visualize drought and signs of environmental distress [173], [179].

As discussed in Section 3.2.2.1. collecting and displaying disaggregated data is particularly as it gives people indications about how much water is used, where and when [55], [57], [90], [91], [364], [365]. Individuals appreciate receiving details about the water consumption of each room and individual fixture [64], [90], [108], [175], [317]. Similarly, they like being able to view their consumption depending on the time of the day, the day of the week and the season and should be able to switch between these displays [90]. All these features facilitate the identification of the most water-using events and appliances within the house [53], [366], [379]. It therefore allows people to target their conservation efforts towards specific activities and devices [53], [90], [318],

[366], [379]. That way, feedback serve as a learning tool allowing consumers to learn about their consumption by experimenting [270].

#### 3.3.2.3. Essential Features

##### Social Media

As discussed in Section 3.2.1.3.5 and in line with the Social Cognitive Theory (Section 2.2.9), being confronted to the sustainable attitudes of their peers encourages people to conserve resources [88], [250]–[252], [329]. As a result, social media efficiently promote environmental behaviours, especially when it shows the actions of valued and respected peers [176], [177], [186]. By increasing people's awareness of social norms, social media help shape behaviours [177]. During the last few years, social media have become part of most people's daily lives. It can be described as "the forms of electronic communication through which users create online communities to share information, ideas, personal messages, and others (e.g. videos)" [380]. Nowadays, Facebook, Twitter, Youtube or Instagram are the most well-known and commonly-used social networks [380]–[382]. Two billion users log in monthly on Facebook against 328 million monthly active users for Twitter [383], [384]. Social media has thus become a tool of "massive real-time social sharing and comparison" [254], [353].

When implementing new applications or interfaces, it is therefore important to know that people appreciate having access to social media [214], [385]. It encourages actions and increases their engagement [385]. In their study, [214] developed a mobile application to reduce energy consumption and linked it to the users' Facebook account to allow them to challenge their Facebook friends during a week-long energy saving competition [214], [254]. Participants could post the results of their conservation efforts on their Facebook wall and were ranked based on their scores [214]. That kind of online activity can enhance users' prosocial reputation by making their environmental actions public, as discussed in Section 2.2.3 [208]. This increased connectivity also encourages competition and collaboration to save resources [353].

##### Challenge and Goal Setting

As mentioned in Section 3.1.2, setting goals is part of the CBSM methods to engage people in environmental actions [273]. Once people commit to reaching a goal or to performing specific actions, they make more efforts to act in line with their promises [88]. If people express commitment, especially in public, there is a high probability that they will pursue that behaviour [254].

To increase people's motivation to reduce their water consumption, the targeted level of consumption should not be too low nor too high [318]. An easy goal would limit the effectiveness while an unrealistic goal would cause distress [339]. The goal can be set internally by individuals themselves or programmed into the display [254], [339].

Comparing people's current consumption to the goal set can encourage them to save resources [90], [108], [175], [318], [333], [340]. Likewise, historical comparisons between a household's past and current consumption or temporal comparisons between an individual's consumption at different times are efficient in encouraging savings [90], [104], [108], [175], [214], [318], [340]. Individuals remember this kind of information and appreciate receiving it [90], [104], [108], [175], [214], [318], [340]. It also increases their control over the evolution of their usage [333]. In the energy sector, such comparisons led to energy reductions of 10%, lasting over a period of three years [108], [339].

Additionally, people should be reminded of their conservation goal whenever they interact with the display [339]. Likewise, in order to give them a sense of control over their consumption, it is important to notify them of how close they are to attaining their goal [284]. This can be done by showing them their progress and the savings achieved every time they undertake a specific action [254], [284].

### Gamification

To better influence attitudes and behaviours, it is essential to deliver messages at the right time [372]. People are more receptive to environmental messages when they are relaxed, in a good mood and enjoying themselves [328], [338], [372]. Due to their recent development and increased popularity, computer games are starting to be considered as a new way of informing the public [338]. More importantly, by entertaining and educating individuals, they can indeed increase their responsiveness to conservation measures [328], [338], [372].

Gamification is "an informal umbrella term for the use of video games elements to improve user experience and user engagement in non-gaming systems and applications" [353], [386]. It uses game elements such as rewards, token, badges which can encourage behaviour change and keep people engaged in the use of technologies [254], [318], [338], [353]. Gamification has the potential to boost feelings of challenge, achievement and satisfaction [254].

Rewards provided within games do not always have to be monetary [254]. They can be virtual currencies, emotional rewards and rewards associated with status or convenience [254], [337], [339]. For instance, they can take the form of social recommendations and praises, making people feel that they are playing a positive role and carrying out positive actions for society [339], [318].

Gamification includes two types of technologies that need to be distinguished: persuasive games and pervasive games. Both types can influence and motivate environmental actions [372] Persuasive technology can be defined as "the application of psychological principles of persuasion to interactive media to change users' attitudes and behaviours" [254]. It can be used to modify and shape users' behaviours [338], [386]. Persuasive technologies and computers enhance the impact of psychological cues to motivate and influence certain behaviours [267], [338], [372]. The persuasive power of a game lies in the fact that it is a simulated environment in which users can "explore cause-and-effect relations and uncover new behaviours" [338]. For instance, a display informing individuals about the level of carbon dioxide produced by a house becomes persuasive when it also informs about the carbon dioxide produce by different devices [181]. That way, it gives people enough knowledge to act and target specific appliances to reduce carbon dioxide emissions [181].

Pervasive games are distinct from persuasive games as they can be situated in the real world "with real hands-on tasks that require player engagement" [355]. By imitating real-life situations, these simulation games allow users to experience water-saving habits and to understand their positive impact on the environment in an easy and fun way [387]. In pervasive games, real-life activities can be suggested to help participants unlock game levels and sustainable actions performed within households can be rewarded by bonus points [338], [340], [388]. [355] tested a pervasive game "the Power Agent" in households to encourage teenagers and their families to reduce their energy consumption. The pervasive game was connected to the house power meter and to automatic meter readings [355]. The results showed a decrease in energy consumption and a change in behaviour [355]. Knowledge concerning energy conservation strategies and behaviours particularly increased [355]. However, consumption returned to its previous state after the end of the study [355]. Therefore, in order to have a longer-lasting impact, the authors suggest that the game should last longer and that feedback should continue to be sent to assess users' postgame energy-saving strategies [355].

### Virtual Pets

[284] highlight the usefulness of including virtual pets in user interfaces. Research done in conservation psychology indeed considers that animals help human being to connect with nature even though it is yet not clear whether caring for animals leads to environmentally responsible behaviours [267], [389], [390]. In the past, the creation of virtual pets such as Tamagotchis have led people to develop emotional attachment for these creatures that required nurturing interaction [267]. Polar bears are powerful symbols of environmental issues and are directly connected to environmental behaviours [267]. In their study, [267] concluded that the

creation of a virtual polar bear, symbol of climate change, had a positive and significant impact on the actions undertaken by participants. The bear, represented on an ice floe, would react to the commitment to environmental actions. The size of the floe would change depending on the number of actions one committed to undertake [267]. Giving people the possibility to make commitments publicly and to have the status of their polar bear on display helped achieving behaviour change [267]. Additionally, using pets can also encourage viral spread of the use of the interface, i.e. giving a baby polar bear to a friend [284].

By providing individuals with real-time or near-real time information about their water usage, smart meters and user interfaces, available on in-home displays and applications, can promote water savings [273]. Studies conducted abroad and examples of initiatives undertaken in the energy sector give useful recommendations as to the implementation of such tools in the UK to change behaviours and reduce domestic water consumption [55], [57], [91], [357]. They provide various guidelines regarding the aspect of the interface or essential features that it should include. However, the democratisation of these new tools raises questions regarding users' privacy [391], [392],[181], [284]. In the UK, the implementation of smart energy meters is currently facing a large opposition from the public [393]. Similar concerns could therefore appear if smart water meters were deployed nationally. Thus, the following section addresses these privacy concerns light of the current legislation to set this research into a national context and ensure that the limitations to the applicability of such methods in the UK are considered.

#### 3.3.2.4. Privacy Concerns Regarding the Implementation of Smart Meters

Privacy concerns regarding the implementation of smart meters are often based on the fact that these tools are intrusive and that the data collected can be sold to third parties such as insurance companies or the police [393]. In addition, some activities could be deduced by the collection of this data [392]. For instance, collecting water data on a daily or hourly basis makes it possible to know when houses are occupied or vacant [28], [391]. Besides, constantly evaluating people's consumption make them feel like there are under surveillance and can lead to the stigmatisation of some groups of water users [391]. The information collected by smart technology is also vulnerable and risks being hacked, altered or even destroyed by a virus [28], [378], [394]. If people do not trust the security of a system, they might be reluctant to use it [378].

In the energy sector, privacy has been defined as "a probability of detecting a hidden trace of events, given a perturbed or aggregated signal containing such event" [392], [395]. According to the European Commission, this includes data regarding household consumption, personal details or usage data [396]. Smart meter data is considered as personal data and, apart from some

exceptions, is protected under European data protection frameworks and under the 1998 Data Protection Act [397], [398]. Suppliers and other data users have to comply with the requirements imposed in these documents when collecting individuals' data [398].

Thus, since 2013, suppliers can access detailed data up to half-hourly and this data can be used for marketing purposes but only if individuals explicitly consent to it [398], [399]. People can refuse the access to recent data, i.e. for a period of less than a month [398], [399]. Additionally, third parties are only able to access data if individuals agree to it [398], [399]. The UK government is also ensuring that the development of smart meter systems is fulfilling a number of security requirements to reduce the risks associated with the use of these meters [398]. To reassure consumers, the government therefore suggests that suppliers provide consumers with a privacy charter, explaining the regulatory framework protecting them [398]. This is in line with the creation of a Data Protection Impact Assessment template created by the European Commission to help member states ensure that the deployment of smart metering respects people's rights regarding their data and privacy [400].

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Chapter 2 identified a set of socio-demographic factors that need to be assessed via surveys within the studied population to better understand – and ultimately change - water attitudes and behaviours (see Chapter 5). By reviewing behaviour-building and behaviour-changing theories, it also provided the information necessary to form the theoretical framework of this research that will be described in Chapter 6. This theoretical framework will inform the choice of methods of behaviour change that need to be implemented via the user-interface to encourage water conservation. However, it is important to understand how to practically implement these methods. Chapter 3 therefore provided guidelines regarding the most effective means of deploying these methods in order to encourage changes in consumption habits. In Section 3.1, it was first recommended that information should be provided by credible or influential sources and should be tailored to the public targeted [88], [179], [187], [188], [289], [291]. Through examples of UK informational campaigns conducted by water companies and of international CBSM campaigns, it was then suggested that information should be coupled with prompts based on CBSM methods, such as goal setting, to efficiently promote conservation [130], [181], [186], [270], [271], [299]–[302], [309]-[311], [401], [402]. Section 3.2 demonstrated that all these recommendations can be deployed through ICT to better change behaviours on a large-scale.

While many studies about the use of these tools to promote conservation have been conducted in water-scare areas, their impact in places that do not experience water scarcity is currently unclear [55], [57], [91], [104], [357]. It is however crucial to learn from these studies and from initiatives conducted in the energy domain to better implement and validate such tools in the UK. By reviewing the relevant literature, this chapter provided specific guidelines to communicate information and to implement methods of behaviour change. These include recommendations regarding the nature of the information provided, the ideal frequency of feedback and the best ways to present data and information through user-interfaces. This chapter therefore adds to the theoretical framework developed in light of Chapter 2 by considering the practical aspect of designing a user-interface to promote conservation. These practical recommendations and the theoretical framework will fully inform the design of the interface, its visual and content, as described in Chapter 6. The next chapter provides a more global overview of the methodology used to fulfil the research aim and objectives of this project. It justifies the choice of specific research approaches and methods, i.e. surveys and case studies and describes the process of selecting samples and of collecting and analysing the data.

# Chapter 4: Methodology

The literature review detailed in Chapter 2 and Chapter 3 has informed the methodology used throughout this research project. Chapter 2 identified the socio-demographic factors that need to be assessed within the studied population to better understand and modify individuals' environmental attitudes and behaviours (see Chapter 5). By reviewing behaviour-building and behaviour-changing theories, it also provided baseline information that helped to choose adequate methods to implement within the interface to change behaviours and encourage conservation. Chapter 3 then provided practical recommendations based on previous studies to efficiently deploy these methods using ICT in the context of this project. Knowledge drawn from Chapters 2 and 3 therefore forms the theoretical framework of this research that guided the design of the user-interface to efficiently promote behaviour change. To fulfil the research aim and objectives, the author believes that it is necessary to detail the choice of methodological methods used to (a) collect socio-demographic data, (b) assess participants' awareness and beliefs regarding water conservation, (c) design and test the interface and (d) identify the most effective methods of behaviour change. Therefore, this chapter will rationalise and explain the philosophy of this research (4.1.1), its design (4.1.2), the approach followed (4.1.3), the methodological choices (4.1.4), the strategies (4.1.5), the time horizon (4.1.6) and finally the techniques and procedures (4.1.7) used to fulfil the main research aim and the research objectives.

The thesis intends to fulfil the following aim: **Understand whether a user-oriented on-line water feedback system is able to foster improved water-saving behaviours through the promotion of increased awareness of water consumption and the encouragement of positive behavioural and lifestyle changes.**

To reach this main research aim, the following objectives have been formulated:

- Objective 1: Identify water users' current level of awareness of their water consumption and attitudes towards water usage.

This objective is fulfilled through the analysis of people's perceived need to use water more sustainably, their current perceptions of their own water usage and their perceived self-identity in Chapter 5 (see Table 4-1).

- Objective 2: Assess the current level of preparedness for change among water users.

This is assessed through individual's current reported water habits, their willingness to change their habits and to use and invest in a device to help them save water in Chapter 5 (see Table 4-1).

- Objective 3: Identify the methods of encouraging behaviour change and water savings that are most effective across consumers with differing views.

This objective is fulfilled through the evaluation of the impact of tips and advice and of environmental, social and economic information on people's behaviours in Chapter 7 (see Table 4-1). This include assessing individual's perception of social influence, their financial interests, their environmental knowledge before and after intervention and their response to tips and advice provided. It also requires evaluating whether increasing people's awareness of their own consumption can encourage water conservation.

- Objective 4: Determine whether the use of near real-time user-orientated water feedback system promotes behaviour change and water conservation.

Fulfilling this objective requires an understanding of whether the use of ICTs is adapted to promote water conservation and behaviour. This is assessed through individuals' degree of familiarity with new technologies, their use of the interface and its impact on their water consumption in Chapter 7 (see Table 4-1).

Table 4-1. Chapters answering each research objective.

| Objectives | Chapter 5 | Chapter 6 | Chapter 7 | Chapter 8 |
|---|---|---|---|---|
| **OBJ1** | X | | | X |
| **OBJ2** | X | | | X |
| **OBJ3** | | X | X | X |
| **OBJ4** | | X | X | X |

For more clarity, this chapter refers to Saunders' Research Onion as a basis for discussion (see Figure 4-1) [1], [536], [537]. The author believes that this 'onion' is a good way to explain rigorously the methodological processes followed in the context of this research. According to [1], the research process is composed of different layers [1]. Thus, this chapter starts by first describing the philosophy underlying this research project and underpinning the choice of research methods. It then explains the purpose of the research design and the research approach undertaken before detailing the methodological choices and the research strategies used. Finally, the time horizon of the study and the techniques and procedures used to collect and analyse the data are described.

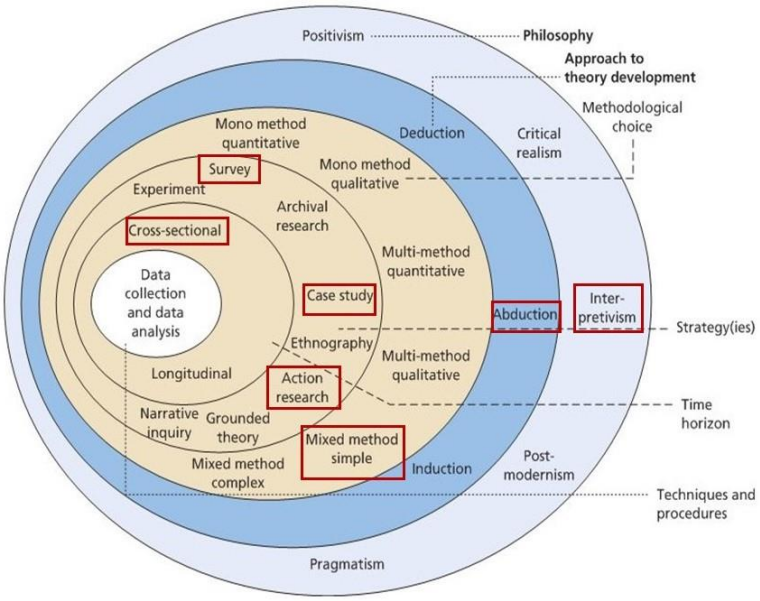


Figure 4-1. Methodological choices underlying this research project (in red boxes) based on Saunders' Research Onion [1].

## 4.1. Research Philosophy

Research philosophy is described as 'a system of beliefs and assumptions about the development of knowledge' [1]. Research philosophies are closely related to research paradigms, that can be defined as 'the philosophical intent or underlying theoretical framework and motivation of the researcher with regard to the research' [403]. The choice of the research philosophy depends on the research objectives, on personal beliefs and values and on the philosophy typically chosen in a discipline [1], [404]. The interdisciplinary aspect of this research makes it challenging to choose an appropriate philosophy. The focus of this research is to observe people's behaviours regarding water consumption and attempt to achieve behaviour change

using adequate behavioural strategies implemented through ICT. Therefore, this research lies in both the information systems and in the social sciences domains. These two disciplines traditionally rely on two different research philosophies.

Information systems, as a discipline, relates to 'the development and use of information systems by individuals, groups, organizations and society, where usually those information systems involve the use of computers' [404]. This computing discipline includes, among others, information technology [404]. In information systems research, positivism is the most commonly adopted approach [404], [405]. Positivism considers that reality is represented by 'real' objects that have separate existence [1]. Adopting a positivist approach usually involves collecting data about "an observable reality" and searching for "regularities and causal relationships" [1]. It aims at giving a clear and objective interpretation of the reality [406], [407]. The researcher is independent and value-free from the phenomena observed [406], [407]. Following a positivist approach means formulating and testing an hypothesis, principally through quantitative data analysis, to obtain 'time- and context- free results' that can be generalised [404], [407]. While positivism is still the predominant philosophy in information systems research, it seems that interpretivism is more and more adopted and accepted in that domain [404], [408], [409]. In information systems research, interpretivism is particularly useful to understand the context in which the information system is implemented and its influence [408], [410]

Similarly, although positivism used to be the dominant philosophy adopted in social sciences research, interpretivism is now widely used [411]–[414]. Interpretivism aims at understanding and interpreting social worlds and contexts [1]. It argues that human beings and their social environments cannot be studied in the same way as physical phenomenon [1], [407]. Unlike these phenomena, human beings create meanings that need to be interpreted and studied [1], [407], [412]. Moreover, these meanings 'exist only by social agreement or consensus among participants in a [given] context' [412], [415]. They reflect multiple social realities that cannot be generalised [1]. Interpretivist researchers needs to enter participants' world and understand their point of view [1], [407], [412]. Therefore, their values, actions and beliefs also influence the research process [404]. Interpretivism traditionally uses qualitative data collection methods [407], [412].

While this research aims at fulfilling a research aim formulated based on the literature, just like in positivist research, the research process considers different realities and is conducted in a specific context [404], [412], [415]. The participants' perceptions, attitudes, and habits are assessed under specific circumstances to fulfil the research objectives. A similar study conducted in a different environment might produce different results. The results can be subjected to

multiple interpretations based on already existing theories and, for some, cannot be generalised [404], [407].

As philosophies are often characterized by the methods they use, it is important to mention that, as described in Section 4.1.4, mixed methods are used in this research to fulfil the aim and objectives. A positivist approach would suggest a predominant use of quantitative methods while an interpretivist approach would require the use of more qualitative methods [1]. However, the qualitative aspect of this research, i.e. the focus group and structured interviews, and the samples used suggest that an interpretivist approach might be adapted [404]. Additionally, as explained in Section 4.1.1, this research project follows an action research method. Action research is often related to the interpretivism paradigm [404]. While it is now used in information systems research, this method is commonly associated with social sciences and is "suited to study change processes in social contexts" [410], [416], [417]. It requires the researcher to work in a specific social setting, to understand people's views and perceptions of their world and to encourage different viewpoints, new perceptions and changes that can be perceived as improvements [404].

While it is argued that positivist and interpretivist philosophies can be combined, some authors suggest to align with a single philosophy [403], [418]–[420]. Thus, while this research tends towards a positivist philosophy in many aspects i.e. in some of the research methods employed and in the approach undertaken, interpretivism seems to be the most adequate philosophy to adopt because:

- individuals and their social, psychological and behavioural characteristics are at the centre of this project,
- the nature of the research objectives and the results require a certain degree of interpretation,
- the nature of some of the objectives requires qualitative research to get an in-depth understanding of the phenomena studied,
- the study conducted is context-specific,
- the methods used include qualitative data collection methods and small samples,
- some of the results do not aim at being representative of a wider population and cannot be generalised.

Following this philosophy, the next section describes the design of the research and the procedure followed over the course of this project to address each research objective.

## 4.2. Research Design

Research can have an exploratory, descriptive, explanatory or an evaluative purpose or combine some of these purposes [1], [421]. A descriptive research aims at developing an accurate description of persons or situations [1], [422], [423]. Survey research is therefore suited to this research purpose [423]. In social sciences, descriptive research is necessary to understand the extent of social problems, to encourage social action and to implement 'well-targeted social policy interventions' [422]. Descriptive research can be used in conjunction with an exploratory or explanatory research [1]. Explanatory research studies an issue or a situation to explain the relationships between variables [1], [423]. It usually includes the use of quantitative methods such as surveys or experiments [423]. Exploratory research aims at learning more about a specific topic, issue or phenomenon through open questions [1], [423]. It implies searching the literature on the subject, interviewing experts in a specific field or conducting focus groups [1]. Qualitative methods are particularly suited to this purpose [423]. Exploratory research is also flexible to change and allows the researcher to take different directions depending on the results obtained [1]. Finally, evaluative research aims at assessing the efficiency of the object studied [1].

Due to the nature of the research objectives, this research is divided into three phases, combining different purposes. These three phases all aim at fulfilling the research objectives, as detailed in Figure 4-2.

| | | **OBJ1**: Identifying water users' current level of awareness of their water consumption and attitudes towards water usage. | **OBJ2**: Assessing the current level of preparedness for change among water users. | **OBJ3**: Identifying the methods of encouraging behaviour change and water savings that are most effective across consumers. | **OBJ4**: Determining whether the use of near real-time user-orientated water feedback system promotes behaviour change and water conservation. |
|---|---|---|---|---|---|
| 2014 | Ask Cardiff Questionnaire | X | X | X | |
| | WISDOM Questionnaire | X | X | X | X |
| 2016 | Structured interviews 1 – Water consultation in households | X | X | X | X |
| | Water experts consultation 1 | X | X | X | X |
| 2017 | Structured interview 2 in households | | X | X | X |
| | Water Experts consultation 2 | | | X | X |
| | Case study in office setting | | | X | X |
| | Questionnaire in office setting | | X | X | X |
| | Focus Group | | X | X | X |

Figure 4-2. Methodological choice for each objective.

**Phase 1:** The first phase of this research is mainly based on quantitative methods and follows a descriptive and exploratory purpose. Since surveys are useful tools to learn about people's beliefs and attitudes towards water conservation, it seemed necessary to use them in the first stage of this study to answer OBJ1 and OBJ2 [419], [424]. That way, they help producing a quantitative description of the population studied [425]. The first water experts' consultation is then conducted to learn more about experts' views on behaviour change and water consumption at large and provides complementary answers to OBJ1 and OBJ2 (see Figure 4-3). This consultation and the surveys are all conducted using online questionnaires, sent via emails. Additionally, to get baseline information about people's attitudes, water practices and households' characteristics, a first set of structured interviews is conducted in selected households. The results obtained and the relevant literature described in Chapters 2 and 3 help shape the behavioural strategies implemented in the design of the user-interface in phase 2.

**Phase 2:** Based on the results obtained in phase 1 and on the literature review, the design of the user-interface includes the best behavioural strategies to increase users' awareness of their consumption and of water issues and to better encourage domestic water savings. Details regarding the choice of these strategies and their implementation in the interface are described in Chapter 6 (see Figure 4-3).

**Phase 3:** This final phase is evaluative and used qualitative data collection methods. The aim is to test the user-interface in a real-life context: in households and in a work environment. First, experts are asked to give their opinion on the interface, after having accessed it online, via a second water experts' questionnaire available online. This brings informative details to further answer OBJ1, OBJ2 and OBJ3. The interface is then tested in volunteered households during a quick experimental trial. Participants are given access to the interface for a few minutes and are asked to assess its usage through a structured interview. This helps individuals visualize the potential use of this tool in their houses and gives indications as to the impact of this device in households. This therefore helps fulfilling OBJ3 and OBJ4. Finally, the user interface is implemented in an office setting for a period of two weeks. The water consumption of the building had been monitored a few weeks earlier. However, due to the removal of the meter prior to the study, the interface displays randomised data that was previously collected. During this period, individuals working in this office can access the interface at any time. After two weeks, the interface is removed and an online questionnaire is sent to evaluate its use within the office over the course of this trial. A focus group is then conducted to get more in-depth information about the interface and its impact on participants' knowledge and attitudes towards water conservation. This helps fulfilling OBJ3 and OBJ4.

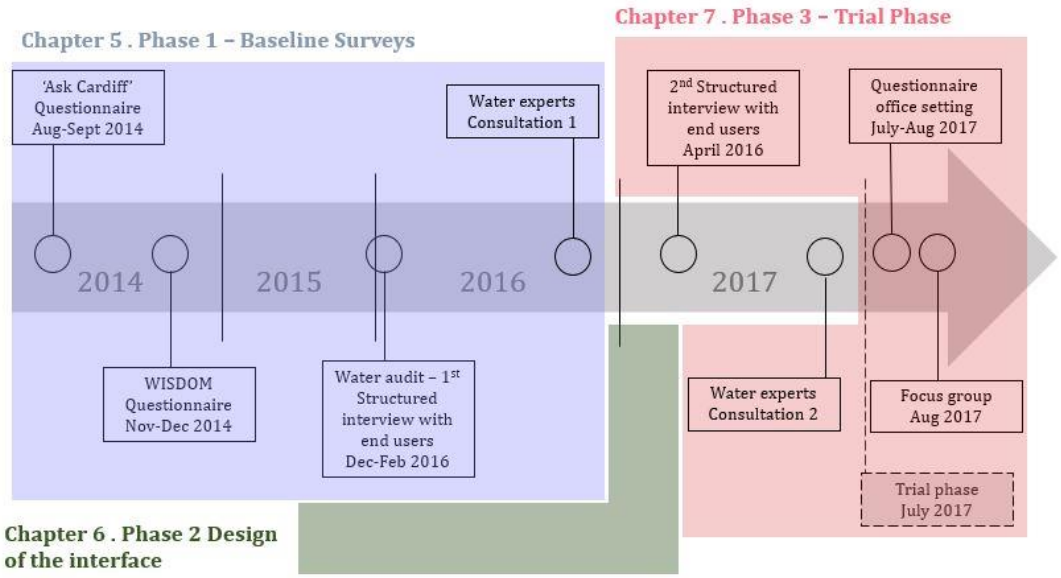


Figure 4-3. Description of each phase of the study in the following results chapters.

This section has described the design of the research and the procedure followed to fulfil each objective using the methods described in Section 4.1. The methodological choices forming the core of this research procedure have been influenced by the best practice in information systems and in social sciences research. They are described in more details in the following sections of this chapter.

## 4.3. Research Approach

There are two different types of research approaches. Deduction requires (a) formulation of a hypothesis based on existing theories, (b) testing of this hypothesis to confirm or reject it and finally (c) revision of the theories if necessary [414], [426]. Conversely, induction means (a) searching for patterns emerging from the collection and analysis of data, (b) developing theories resulting from the observations made on the results and (c) testing and retesting these theories using hypotheses [426], [427].

Deductive or 'theory testing' approaches are traditionally associated with quantitative research while inductive or 'theory building' approaches tend to be linked to qualitative research [414], [422], [428]. Therefore, deduction is more commonly found in positivist paradigms while inductions characterize interpretivist paradigms [414], [426]. However, these typical associations can be overcome and it is better to think of these two approaches as tendencies rather than as distinctions [414], [428]. Indeed, deductive approaches are commonly used in social research, typically more interpretivist [414], [419]. Positivism research can also include both deductive and inductive strategies [414]. Moreover, these two approaches can sometimes

be combined [429]. Combining deductive and inductive approaches can be referred to as an 'abductive approach' [1]. An abductive approach uses elements of deduction and induction to overcome the weaknesses of the two approaches [1]. It is an useful approach to explore a phenomenon in depth[1].

In the context of this research, Chapters 2 and 3 considered the relevant literature and theories to provide a basis for research on behaviour change, water attitudes and behaviours and technology usage. Most of the theories reviewed are widely-used and accepted theories and it seems important to rely on them to better undertake this research process and fulfil the research objectives and the main aim. In this regard, this research partially follows a deductive approach [1]. However, this research also builds on existing theories, adding to the current literature by testing a complete set of methods of behaviour change through an innovative user-interface. The theoretical framework used is then discussed in light of the results obtained. As such, this project can also be considered as partly inductive. Thus, due to its mixed nature, this present research is best qualified as abductive [1], [414], [429].

## 4.4. Methodological Choices

Research methods are quantitative, qualitative or mixed [1], [404]. Quantitative methods are traditionally associated with a positivist philosophy while qualitative methods are commonly found in interpretivism [1]. Yet, data collected through a quantitative method, such as survey, can also fit into an interpretivist approach, especially when it is based on the participants' opinions [1]. In fact, no research paradigms prohibits or prescribes the use of a particular method [403]. Taking a mixed position and using mixed methods can sometimes give the researcher a better chance to fulfil the research objectives [407]. More specifically, qualitative data can complement the use of quantitative data when it comes to assessing behaviours and attitudes [430]. According to [406], quantitative and qualitative methods can therefore be used within any research paradigm. The choice of methods depends on the research aim and objectives and on the resources, time and skills available [428]. Moreover, subjectivity exists when analysing both types of data [431]. It lies in the choice and interpretation of the data analysed but also in the design of the collection methods [431]. Thus, qualitative and quantitative analysis are both influenced by the researchers' characteristics and its disciplinary approach to a certain extent [432].

In the context of this research, both quantitative and qualitative methods seem appropriate fulfil the first few research objectives and understand (a) water users' current awareness of their water consumption and attitudes towards water usage and (b) their current level of

preparedness for change. Using quantitative methods, such as surveys and questionnaires, allows the use of larger samples which seem suitable to get initial and global answers to these questions [404]. On the other hand, qualitative data, collected through structured interview and a focus group, can provide in-depth knowledge and explanations about the diverse perceptions and attitudes regarding water consumption [432]. As qualitative research do not aim at being representative of a wider population but aim at capturing the diversity of responses to phenomena, smaller qualitative samples can also be used in this study [432], [433].

On the other hand, the following objectives aim at (a) identifying the methods of encouraging behaviour change and water savings that are most effective across consumers with differing views and (b) determining whether a near real-time user-orientated water feedback system is an adequate tool to promote behaviour change and water conservation. To fulfil these objectives, it is most adequate to test the water feedback system on individuals. This can be done using qualitative methods, such as a case study, a focus group and structured interviews, to better understand people's experience with the interface. Therefore, using mixed-methods seem to be the most adequate methodological choice in the context of this research.

## 4.5. Research Strategies

The research strategy refers to the approach undertaken to fulfil the research objectives [404]. It is 'a plan of action to achieve a goal' [1]. A variety of research strategies can be used in a research process [1], [404]. Just like research methods, the choice of research strategies should be guided by the research objectives, the research philosophy, approach and purposes but also by the existing knowledge, time and resources available [1]. This research project uses three different strategies: action research, used as the overarching strategy, case study, and surveys.

### 4.5.1. Overarching Strategy: Action Research

Action research was originally developed by Lewin in the field of psychology research to find treatments and solutions to psychological and social disorders that arose in patients traumatised by their World War II experiences [404], [416]. As there was no initial theory for such treatments, scientists had to plan, intervene and reflect upon their interventions to find adequate solutions [404]. Therefore, action research is "an interventionist approach to the acquisition of scientific knowledge that has sound foundations in the post-positivist tradition" [416]. Action research was ignored for a long time in information systems studies but aroused an increasing interest in the 1990s with contributions such as[436], [410], [434]. It is considered as "ideally" suited to the study of information systems and technology and to their use in a "human

context" [416], [417]. For instance, it can be used to study people's interactions through internet or to modify people's behaviours in online groups [404].

The definition proposed by [435] suggests that:

"Action research simultaneously assists in practical problem-solving and expands scientific knowledge, as well as enhancing the competencies of the respective actors, being performed collaboratively in an immediate situation using data feedback in a cyclical process aiming at an increased understanding of a given social situation, primarily applicable for the understanding of change processes in social systems and undertaken within a mutually acceptable ethical framework".

Action Research is characterized by (a) the involvement of the researcher that will benefit both the researcher and participants, (b) the immediate application of the knowledge obtained and (c) the link of theory and practice within the research [416]. The acquisition of knowledge is an "active process" that allows the redefinition of beliefs and theories according to the outcomes or results obtained [416]. Action research enables change in the way people live and makes the connection between the academic world and the "everyday world of most people" [404]. It aims at achieving action outcomes or 'practical achievements in the problem situation' and research outcomes 'learning about the processes of problem-solving and acting in a situation' [404].

Action research is compatible with different research philosophies and methods [404]. This process can therefore be underlined by a interpretivist approach, using quantitative and qualitative methods [404]. The lack of impartiality of the researcher, the difficulty to generalize the results or to repeat the research processes, due to the unique settings in which they are conducted, indeed seem particularly adequate under an interpretivist approach [404], [416]. This does not necessarily mean that all the results obtained using action research cannot be generalized. Some environment might be similar or "typical of other settings" leading to the possible application of the findings to other situations [404]. Moreover, models, theoretical and methodological elements used in action research are "forms of generalizations that often have a wider applicability" [404].

The use of action research seems particularly adequate to this research project. First, a key aspect of this research is to answer RQ4 by designing and testing a user-interface. Information technology is part of the information system discipline [404]. Looking at the literature on the subject, action research seems to be the appropriate method to study information system and technology in a human context [416], [417]. In addition, action research is also recognised as a useful method in social sciences research and can be deployed in the context of an interpretivist

philosophy using of mixed methods [404], [416]. More importantly, action research enables change in the way people live [404]. This is particularly relevant in the context of this research project as the implementation of the user interface aims at promoting behaviour change and increased awareness of water consumption.

To design and test an efficient user-interface, it is important to conceptualize action research methods following specific guidelines. A *framework of ideas* or the theoretical base of the research needs to be established before creating and adopting a *problem-solving methodology* [404], [434], [436]. It is then important to choose *an area of application* or 'a real-world problem situation' where the methodology is applied based on the theoretical framework to encourage and guide people in achieving changes [404], [434], [436]. Actions taken in the area of application should be based on the framework and methodology developed but these two elements can be modified if necessary [404]. In the context of this research, it seems crucial to understand people's attitudes and beliefs about water conservation prior to implementing the user-interface. This implies answering RQ1 and RQ2. This knowledge, the literature and relevant theories will form the 'framework of ideas' or the base of the action research process. This base will then inform the 'problem-solving methodology' - in this case, the design of the interface - to bring changes to the 'area of application' – domestic water consumption. Using a cyclical research process, linking theory and practice and integrating knowledge to better design the user interface are necessary to better fulfil the research aim [416]. It is however crucial to appropriately choose the methods that will form the core of this cyclical research process. The choice of these methods is detailed in the following sections.

### 4.5.2. Additional Strategies

To better fulfil the research aim and objectives, the action research process integrates two other types of strategies: surveys and a case study.

#### 4.5.2.1. Surveys

Surveys conducted for research purposes aim at collecting standardized information, developing a quantitative description of the population studied and studying the relationships between variables [425]. The use of surveys seems like an evident choice when it comes to learning about people's beliefs, identities and values [419], [424]. It can help 'conceptualize culture as beliefs and attitudes'[419], [424]. Using surveys allows the gaining of similar information from a large group of people through predefined and structured questions and leads to quantitative data analysis [404], [425]. It is commonly associated with the positivist philosophy and therefore largely used in the domain of information systems [404], [425]. However, it is also commonly found in social research [422], [437]. Surveys are compatible with

the use of a deductive approach and exploratory and descriptive research [1]. They include the use of methods such as questionnaires, interviews or observations [404]. Results obtained through surveys allow the identification of common patterns [404]. They can be generalized and be considered as representative of the whole population [1], [404]. Moreover, they can be re-tested and replicated to confirm or refute original findings [404].

Surveys appear as the most adequate strategy to answer RQ1 and RQ2. The aim is to understand the global context in which the user interface will be implemented and more particularly to learn more about water user' current perceptions about their consumption, their level of preparedness for change and their attitudes towards water conservation. For practical reasons, surveys also seem like the most appropriate strategy to get water experts' opinions on the use of the interface. However, compared to other research strategies, surveys can be restricted in the range of matters they cover [1]. For instance, shorter questionnaires are more efficient and more appreciated by respondents, than long questionnaires [1]. This limits the number of questions asked [1]. Therefore, as mentioned in Section 4.1.7., this research project not only includes questionnaires but also different data collection methods.

#### 4.5.2.2. Case Study

It is first important to note that the term "case study" can refer to both a unit of analysis and a research method [410]. Case study as a unit of analysis refers to "a scenario to which [researchers] have applied their proposed modelling technique, method or program" [404], [410]. A case study as a research method is an in-depth exploration from multiple perspectives of the complexity and uniqueness of a particular project in a "real life" context' [438], [439]. This setting existed before the launch of the study or research and will exist after it ends [404]. It focuses on one instance of the object being investigated and takes into account "factors, issues, politics, processes and relationships" surrounding it [1], [404]. It can be based on a single case or on multiple cases [1], [404]. Case study is suited to both positivist and interpretivist philosophies, to deductive or inductive approaches and can include qualitative and quantitative methods [1], [404], [419], [440]. It is commonly used in social sciences but can be included in information systems research [409], [437], [441], [442]. It can also be used as a complement to a deductive approach, in an exploratory stage [1]. This is then referred to as 'indicative case study research' [1]. Case studies are thought to have limitations when it comes to generalizations as research environment in which they are deployed might have "unique features" [404]. However, Despite focusing on a particular case, case studies can be generalized if the case chosen is "typical of other cases" [404], [440], [443].

Survey research can be improved by the joint use of quantitative and qualitative research methods [444]. Therefore, the use of case study appears useful in the context of this research. While surveys provide a wider understanding of people' perceptions and attitudes, a case study allows a detailed exploration of the use of the user-interface in real-life settings [438], [439]. This is done through the implementation of the user-interface in an office setting during the trial phase. Moreover, to determine the behavioural strategies that have more impact on individuals, participants' interaction with the interface needs to be evaluated. This means identifying the features that they look at the most and understanding the frequency at which they check the interface.

## 4.6. Research Time Horizon

Studies can be either cross-sectional or longitudinal [1]. Cross sectional studies 'involve the study of a particular phenomenon (or phenomena) at a particular time'[1]. A study is defined as longitudinal "when the research takes place over time, with two or more repeated measurements of the same sample of population over a period of time" [445]. It analyses processes and relationships that are continuous or that change over time [404].

In the context of this research, people's attitudes and beliefs towards water conservation and their use of the interface are assessed through different samples. While some respondents took part in more than one survey in the context of this research, they were asked different questions in each survey and were consulted at particular times and not over a specific period of time. Therefore, this research project is cross-sectional in nature.

## 4.7. Techniques: Data Collection and Analysis

### 4.7.1. Data Collection Methods

Questionnaires are widely used techniques in survey research [422]. A questionnaire is a "pre-defined set of questions (sometimes called items), assembled in a pre-determined order [404]. Responses to those questions lead to the collection, analysis and interpretation of data [404]. In this study, the use of questionnaires seems particularly necessary to answer RQ1 and RQ2. It helps assess and identify common patterns in people's beliefs, identities and values regarding water consumption using large samples of population [404], [419], [424], [425]. This fulfils the descriptive purpose of this research.

Structured interviews can also be used in survey research [1], [422]. Structured interviews are interviews in which respondents are asked the same standardized questions [1]. Prior to

implementing the interface, it is important to get some baseline knowledge about people's habits, attitudes and perceptions regarding water consumption. In the context of this research, this is done through a 'water consultation' which can be described as a structured interview since it includes standardized questions. The questions are asked in person to each participant, following a predefined questionnaire. More importantly, this same method is used to collect participants' impressions on the use of the user-interface in a domestic setting. After testing the interface and its features during a quick experimental pilot, householders must answer a set of interview questions about the interface.

Focus groups are 'data collection techniques that capitalizes on the interaction within a group to elicit rich experiential data' [446]. It gathers individuals who share similar socio-demographic characteristics to discuss a specific topic of interest [431], [446]. In a way, focus groups can be described as group interviews [447], [448]. In the context of this study, focus groups are particularly useful to know more about people's perceptions and use of the user interface and to complement the results obtained from questionnaires. In that sense, using a focus group therefore fulfils the exploratory purpose of this research.

### 4.7.2. Selection of the Samples

Using a simple random sampling method, the 'Ask Cardiff' survey (Appendix A) was sent to a random sample of 3000 households within Cardiff. This sampling method was performed by Cardiff City Council who sends the survey every year to Cardiff inhabitants. This method reduces the potential human bias and makes it possible to obtain a representative sample of the population studied [1]. Simple random sample allows researchers to make generalisations from the sample studied [1].

In accordance with the partners involved in this project who distributed the other questionnaires and conducted the structured interviews, a self-selection sampling method was used for the rest of the surveys. This method gave a wider access to participants. It is commonly-used in social sciences research, along with convenience sampling [413], [449]–[451]. It however implies that respondents to the WISDOM survey and structured interviews are all volunteers who agreed to participate in this study. Likewise, this method was used during the implementation of the interface in the office setting. While a specific office was chosen for the trial phase, people working in it were free to interact, or not interact, with the interface. The questionnaire designed to collect opinions on the use of the device was sent to the entire office but only responses from individuals who used the interface were analysed. The self-selection sampling method was also used to find participants for the focus group, among the persons who tried the interface in the office setting. However, in this context, the sampling method can also be considered as convenience sampling

as it was based on the participants available at that time [413]. This resulted in only four individuals taking part in the discussion. While this sample size is relatively small, it fits into the recommended sample size for a focus group in thematic analysis [452], [453]. Details of the selection of samples for each study are described in Chapter 5 and 7.

The first water experts' consultation was conducted using another non-probability sampling techniques: the snowball sampling method. Snowball sampling gives an easy access to a population that can be difficult to reach or to identify [454]–[456]. In this situation, it allowed the author to reach a larger number of water experts. Some participants, members of research groups and experts met at conferences, were contacted directly and asked to send the survey to other water experts they knew. The second water experts' consultation was sent to some of the experts that had already taken part in the first consultation.

### 4.7.3. Data Analysis Methods

The quantitative data obtained from the surveys has been collected in the form of excel sheets and transferred onto SPSS Software. It was then prepared for analysis, coded and cleaned. Once ready, the data was analysed using descriptive and frequency statistics. This was particularly useful to describe and summarize the data in a meaningful way and eased the interpretation of the results. To reach conclusions, the data was then analysed using inferential statistics [457], [1], [458]. Depending on the type of variables analysed, this includes tests such as the chi-square test for homogeneity, the chi-square test of independence, the chi-square test for association, the Cochran-Armitage test of trend, point-biserial correlation, Spearman's rank-order correlation, Pearson's product-moment correlation, Somer's *d* tests, linear regressions and binomial logistic regressions. Odds ratios defined as a 'measure of association between an exposure and an outcome or the odds that an outcome will occur given a particular exposure' are also often calculated as a measure of effect size [459], [460].

Due to the small sample size sometimes used in this research, it is however important to be cautious when presenting the results from the inferential statistics analysis described in Chapters 5 and 7. A test of significance is 'a method used to infer knowledge about a population on the basis of a statistic gained from a sample' [461]. The importance of statistical significance has been debated within the literature, especially in social sciences research [450], [462], [463]. Lack of statistically significance can lead researchers to misinterpret their data [464]. [465] highlights that "far too often we deduce 'no difference' from 'no significant difference'". However, statistical significance is neither essential nor sufficient to determine the practical significance of a study [464]. For some, tests of statistical significance are even considered as adding only little value to the products of research [463]. Additionally, tests of statistical significance, such as the *p*-value,

assume random sampling when the sample selection is sometimes biased [462]. They can be misleading when using small samples and are also less relevant when the results of a study are not intended to be generalized [466], [467].

Thus, in addition to *p*-values, reporting confidence intervals and effect size measures, such a Cohen's *d*, even for non-statistically significant results, has been suggested within the literature [464], [468]–[470]. They offer more complete information than null hypothesis significance testing (NHST) and should be used for the interpretation of the results [471]. Effect size allow researchers to described the magnitude of the reported effects to explain the practical significance of their results [472], [473]. For Cohen's *d*, effect sizes can be considered as small (D = 0.2), moderate (D = 0.5), and large (D = 0.8) [472], [473]. For eta squared $\eta^2$ , the benchmarks provided are small ($\eta^2 = 0.01$), medium ($\eta^2 = 0.06$), and large ($\eta^2 = 0.14$) effects [472], [473]. For Cramer's V, the degree of freedom (*df*) should also be taken into consideration as it influences the interpretation of the effect size [472], [474]. For these reasons, effect sizes are included in the description of inferential statistics when appropriate in Chapters 5 and 7. They are estimated by dividing the between-groups difference in mean scores by the pooled within-group standard deviation using online calculators [354], [475], [476]. When this data is not provided, effect sizes are calculated from other available statistical information such as t-tests [354], [475]. Cramer's V, odds ratio, Somer's *d*, eta squared $\eta^2$ and Cohen's *d* are used as measures of effect size depending on the analysis performed and on the type of variables analysed [460], [477].

Concerning qualitative data, thematic analysis is a widely-used analytic method in social sciences research [432], [453]. It implies 'looking for common themes in the data either across instance with one individual or across individuals' [478]. This method is flexible and can be applied in the context of different theoretical frameworks, with any form of qualitative research [452], [453], [479]. It is suitable for the analysis of interviews or focus groups [452]. Thematic analysis follows six steps: familiarization, coding, 'searching' for themes, reviewing themes, defining and naming themes, writing the report [452], [453].

Interpreting qualitative data means understanding individual quotes and finding links and relationships between the data based on criteria such as words, context, extensiveness of comments, intensity of the comments and big ideas [431], [480]. It is recommended that studies using the Framework method should be overseen by an experienced qualitative researcher [432]. In line with this, the qualitative data obtained from the structured interview and the focus groups has been analysed with the help of an experienced researcher in psychology. The discussion from the focus group has been recorded and transcribed. Notes have also been taken to give more details about the participants' attitudes. Because it generated a large amount of data, the data

obtained was reduced according to the initial intention of the study [431]. It was then categorised based on the themes that emerged from it, as identified by both researchers. The results and details of the analysis performed on the quantitative and qualitative data are presented in Chapters 5, 6 and 7 of this thesis.

Based on the literature, this section has explained and justified the choice of methods used in this research to fulfil the aim and objectives. This research follows a specific design and procedure that integrates these different methods and strategies, as described in Figure 4-4.

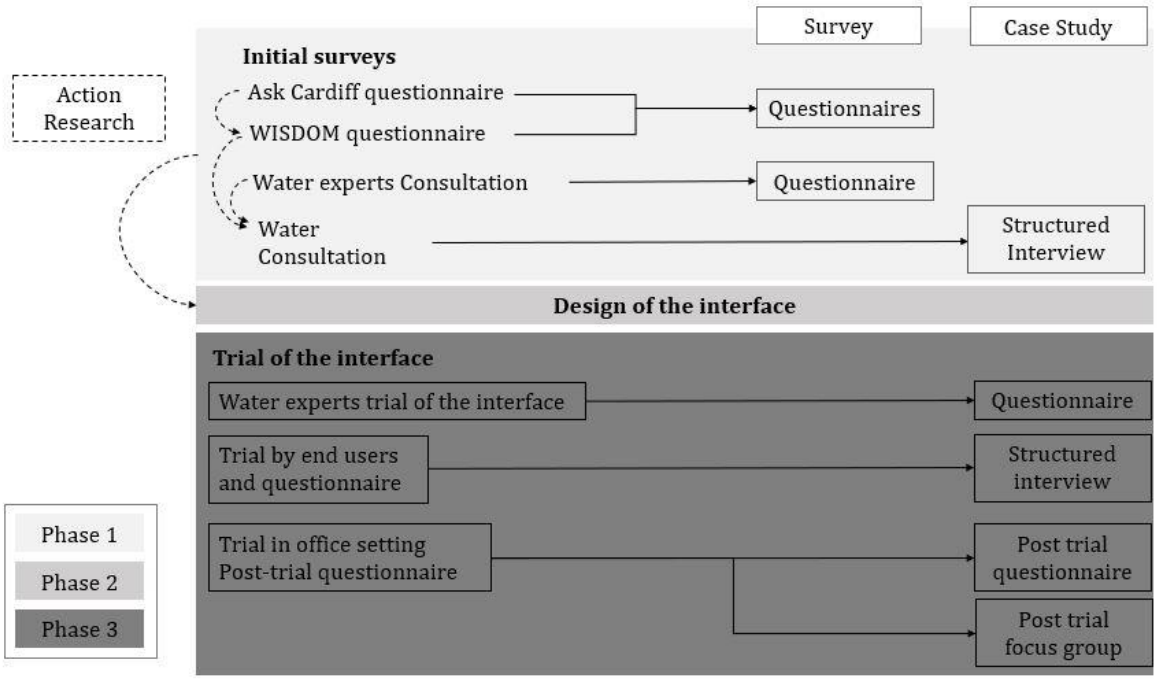


Figure 4-4. Action research process, research strategies and data collection methods.

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This chapter has described the methodology used in this research, from the research philosophy to the data analysis methods, by explaining each methodological choice based on relevant literature and best practice in information systems and social sciences research. Based on this methodology, phase 1 of the research procedure is detailed in the chapter that follows, along with a full description of the design of the surveys and of the data collection and data analysis methods used for each questionnaire, consultation and structured interview.

# Chapter 5: Phase 1: Understanding Current Water Attitudes and Behaviours in Cardiff

This chapter presents the design, collection and analysis of the surveys conducted in the first stage of this research project (see Figure 5-1). The author believes that these surveys are crucial (a) to identify key socio-demographic factors influencing water consumption in the context of this research and (b) to understand current practices, attitudes and beliefs regarding domestic water consumption in Cardiff. To this end, the identification of key socio-demographic factors in Chapter 2 provided a good basis to assess the existence of these factors within the population studied. It is also necessary to assess individuals' current knowledge of water conservation and levels of willingness and preparedness for change. Obtaining this baseline information will indeed help to determine the best ways to encourage water savings in Cardiff households and thus will inform the design of the user interface described in Chapter 6. In accordance with the action research process described in Chapter 4, the results of each survey and their influence on the future stages of the project are described in this chapter.

Each section presents the results of a different survey, divided into descriptive statistical analysis and inferential statistical analysis, conducted using SPSS Statistical Software. The descriptive analysis mainly involves frequency and percentages and gives an overview of initial information obtained about the respondents. The inferential analysis aims at drawing more in-depth conclusions from the data obtained, using correlation, regression and association tests depending on the nature of the variables analysed. Section 5.1 presents the results of the 'Ask Cardiff' survey (Appendix A), the first and largest survey conducted in the context of this project. Section 5.2 describes the findings of the follow-up survey: the WISDOM survey (Appendix B). The first expert's consultation (Appendix C) is reported in Section 5.3. Finally, Section 5.4 focuses on the responses obtained during the first end users consultation, the 'water consultation' (Appendix E), conducted within a sample of households in Cardiff.

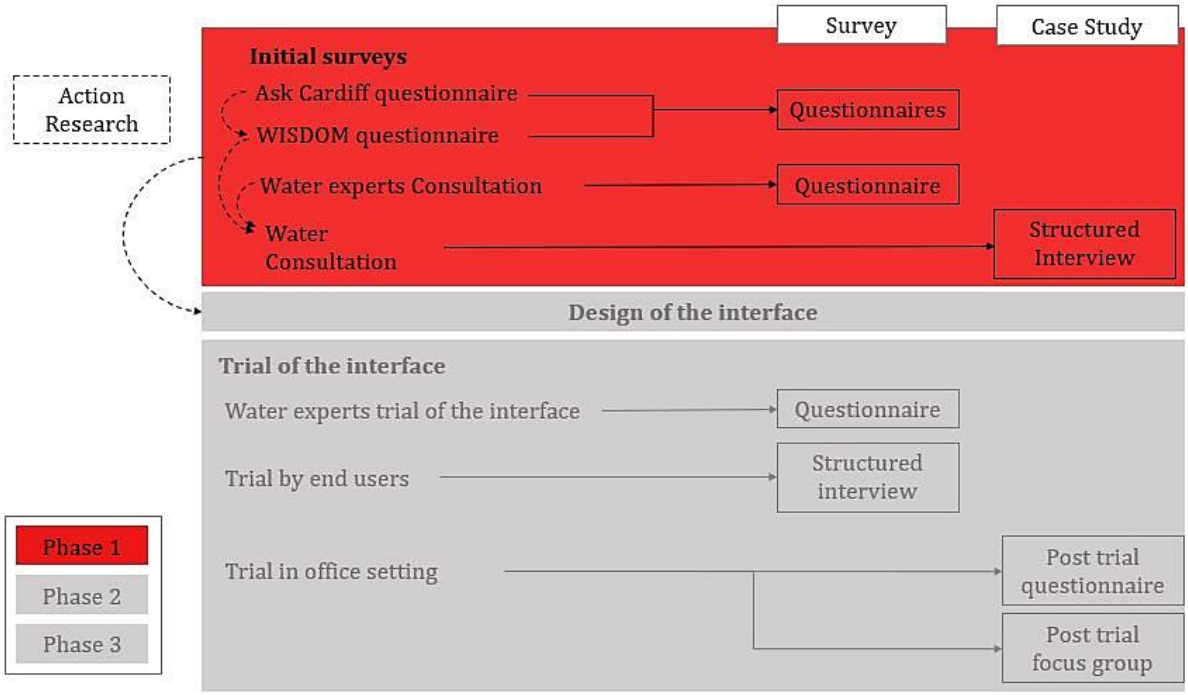



Figure 5-1. Focus of Chapter 5 (highlighted in red).

## 5.1. 'Ask Cardiff' Survey

The 'Ask Cardiff' survey is an annual survey conducted by Cardiff City Council to assess Cardiff inhabitants' views and opinions on the public services delivered by the Council (see Appendix A). In the context of this study, the 'Ask Cardiff' survey refers to the eighteen multiple choice questions related to water consumption that were designed by the author and included in the 2014 'Ask Cardiff'. A link to this survey was sent by Cardiff City Council, via letters and emails, to a random sample of 3000 inhabitants divided in electoral division. 2309 responses were collected and analysed after the removal of invalid data points from the data set. The aim of this first survey was to understand current water consumption trends and attitudes in Cardiff and to assess these trends in relation to RQ1 and RQ2.

As demonstrated in Section 2.1, demographic characteristics impact people's water consumption [54], [125]–[128]. Thus, as described in Section 5.1.1.1, it first seemed necessary to learn about the participants' age, gender and area in which they lived. Some of their households' characteristics were also assessed. These included the number of adults and children living in their households, the type of properties in which they lived and the water-saving devices used within their home.

In order to fulfil OBJ1, it was crucial to evaluate respondents' awareness of their water consumption (Section 5.1.1.2). To do so, multiple choice questions were asked with suggested answers (Appendix A). Their attitudes towards water conservation were also assessed through

questions determining the reasons motivating them to save water. Then, to evaluate respondents' level of preparedness for change and fulfil OBJ2, questions about their current interaction with the water companies and their willingness to invest in water-saving devices were asked. Finally, as detailed in Section 5.1.1.3, their awareness of the price of their water usage were assessed.

## 5.1.1. Results

### 5.1.1.1. Demographics

Looking at the demographics, a slight majority of participants to the Ask Cardiff survey are female participants (52.7%). Most participants are aged over 55 (42.8%) or between 35 and 54 years old (41.1%) (see Table 5-1).

Table 5-1. Age distribution of all respondents

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | 16-34 | 365 | 15.8 | 16.0 | 16.0 |
| | 35-54 | 936 | 40.5 | 41.1 | 57.1 |
| | 55+ | 974 | 42.2 | 42.8 | 99.9 |
| | Under 16 | 3 | 0.1 | 0.1 | 100.0 |
| | Total | 2278 | 98.7 | 100.0 | |
| Total | | 2309 | 100.0 | | |

Respondents mainly live in the Northern areas of Cardiff – Llanishen (6.7%), Whitchurch and Tongwynlais (6.7%), Rhiwbina (6%) - and in areas close to the city center – Plasnewydd (6.1%), Canton (6%) and Riverside (5.3%) - with the remaining participants spread across other city districts (see Figure 5-2).

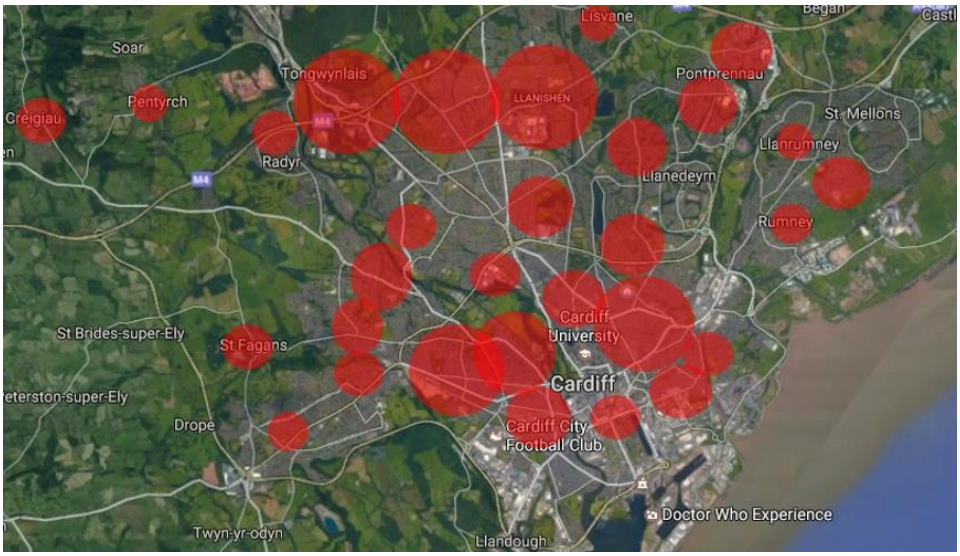



Figure 5-2. Geographical repartition of the "Ask Cardiff" respondents

Regarding the household composition, respondents are living with another adult (58.4%) or are the only adult of the household (23.8%). Children are living in 23% of the households. These include a child aged under 4 in 77% of these households and a child aged between 4 and 18 years old in 86% of these households. Most of the properties are owned with a mortgage (41.5%) or owned outright (40.0%) and include a lawn or garden (82.7%).

Concerning water-saving devices, a little less than half of the respondents have a water meter installed (48.8%). Only 15.1% of respondents have water-saving devices at home. 28.9% affirmed that they own a rainwater harvesting system or a solar water heating system (1.4%).

#### 5.1.1.2. Awareness of Water Usage and Attitudes towards water Conservation

Most respondents reported being aware of the amount of water used by them or their households (58.5%) (see Figure 5-3).

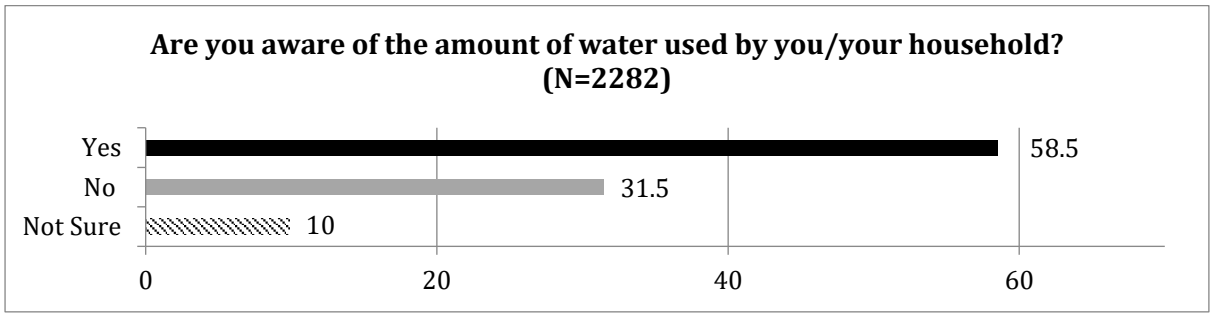



Figure 5-3. Perceived awareness of water usage in household.

Two-thirds of respondents (67.8%) think that they currently do enough to save water and only one in five (21.6%) would like to do more. Among those who believe that they do not do enough to save water, 38.9% need guidance to reduce their consumption. However, a majority (52.4%) feel that they do not need any advice. The majority (92%) of respondents are motivated to save water. Reasons to save water however vary among respondents (see Figure 5-4).

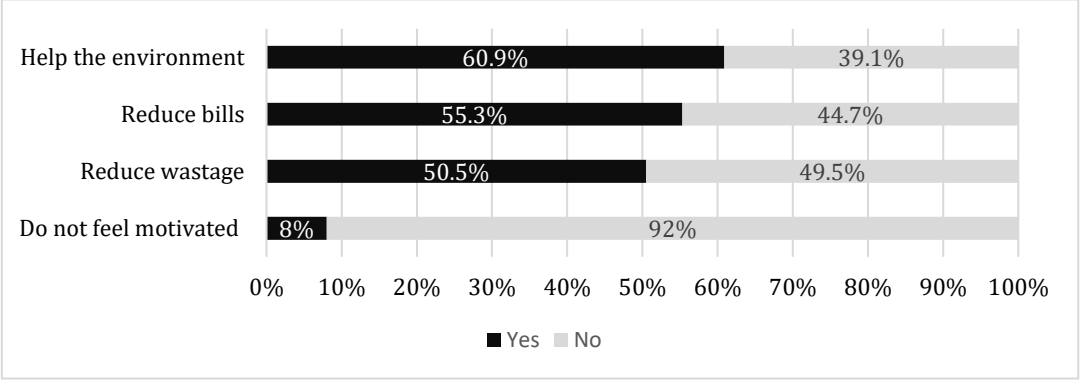



Figure 5-4. Reasons motivating participants to save water.

#### 5.1.1.3. Financial Concerns

Most respondents are aware of how much they pay for their water use (84.9%). More than half (53.1%) however indicated that they would be more careful about their water consumption if they were aware of its costs (see Figure 5-5).

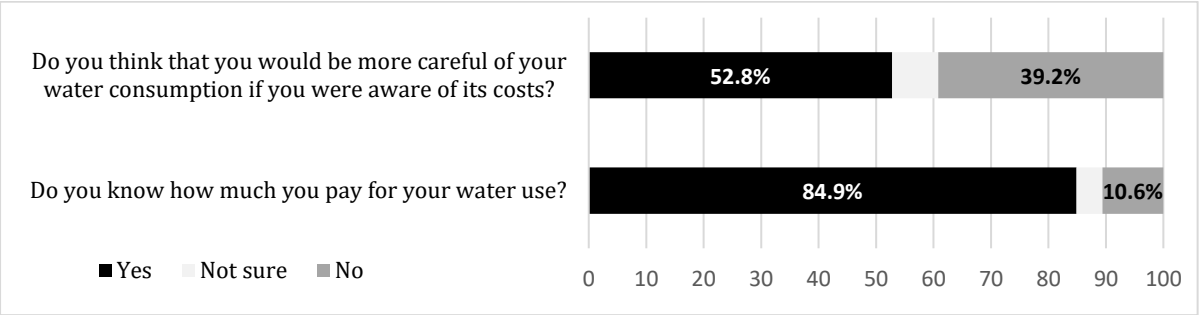



Figure 5-5. Participants' awareness of water prices.

While a large majority of respondents (84.9%) do not have any water-saving devices, only a third (31.3%) would be willing to buy and install these devices within their homes.

#### 5.1.1.4. Interaction with water supplier

A majority of respondents (64.3%) reported not feeling encouraged to save water by their water company.

### 5.1.2. Analysis

While the descriptive analysis of the results is particularly useful to visualize participants' responses and to interpret the results, it is crucial to use inferential statistics to draw conclusions from the data [457], [1], [458]. Thus, various statistical tests suitable to the different types of variables used have been performed to determine associations and correlations between the responses (see Appendix J).

#### 5.1.2.1. Demographics

Concerning demographics, association between gender and saving water to help the environment was tested using the chi-square test for homogeneity (see Table 5-3) [486], [487]. The null hypothesis states that the difference between the population proportions in female and male participants saving water to help the environment is equal to 0. Two samples of 100 males and 100 females were randomly selected. 62 female participants stated saving water to help the environment compared to 55 male participants, a difference in proportions of 0.07. However, there was no statistically significant difference between the two independent binomial proportions ($p$=0.315) and Cramer's V (0.071) suggested a small effect size [472]. Therefore, we

cannot reject the null hypothesis stating that the difference between the population proportions in female and male participants is equal to 0.

A binomial logistic regression was performed to ascertain the effects of age on the likelihood that participants save water to help the environment (see Table 5-2) [488], [489]. There was no studentized residual. The logistic regression model was not statistically significant, $\chi^2(1) = 0.002$, $p$=0.968. The model explained 0% (Nagelkerke $R^2$) of the variance on the likelihood that participants save water to help the environment and correctly classified 61.6% of cases. Sensitivity was 100%, specificity was null, positive predictive value was 61.6% and negative predictive value was null. Yet, the Hosmer and Lemeshow test indicated that the model was not a poor fit ($p$ = 0.550). Age as a predictor variable was not statistically significant, p= .968. However, the odds ratio *Exp*(B) = .997, 95% CI = 0.883 to 1.12 suggests that the odds of saving water to save the environment slightly decreases as age increases [460]. However, paradoxically, the odds ratio of considering water as an important issue in age 35 to 54 versus age 16 to 34 is 1.099 (95% CI = 0.858 to 1.408), 1 in age 35 to 54 versus 55 and over (95% CI = 0.2 to 50.397), 1.025 in age 55 and over versus 16 to 34 (95% CI = 0.802 to 1.311). This shows that individuals are more likely to consider water conservation as an important issue as age increases.

To further this analysis, the Cochran-Armitage test of trend, designed to test association between an ordinal independent variable and a dichotomous dependent variable, was then used to determine whether there was a linear trend between age and the wish to save water to help the environment (see Table 5-3) [490], [491]. The null hypothesis tested was '$H_0$: There is no linear trend in binomial proportions across age categories'. The age categories included were 16-34 (n=363), 35-54 (n=925), over 55 (n=961), and the proportions of respondents who reported saving water to help the environment was 0.595, 0.619, 0.601, respectively. The Cochran-Armitage test of trend did not show a statistically significant linear trend between age and saving water to help the environment. $p$ = .805. Therefore, we cannot reject the null hypothesis and cannot accept the alternative hypothesis.

A binomial logistic regression was performed to ascertain the effects of age on the likelihood that participants save water to reduce bills (see Table 5-2) [488], [489]. There was no studentized residual. The logistic regression model was not statistically significant, $\chi^2(1) = 0.233$, $p$ = 0.629. The model explained 0% (Nagelkerke $R^2$) of the variance on the likelihood that participants save water to help the environment and correctly classified 55.2% of cases. Sensitivity was 100%, specificity was null, positive predictive value was 55.2% and negative predictive value was null.

Here again, the Hosmer and Lemeshow test however indicates that the model was not a poor fit ($p$ = 0.732). Age as a predictor variable was not statistically significant, p= 0.629 but the odds ratio *Exp*(B) = 0.972, 95% CI= 0.867 to 1.09 suggests that the odds of saving water to reduce bills slightly decreases as age increases [460].

Table 5-2. Binary regression analysis results regarding the effects of age on the likelihood that participants save water to help the environment.

| | ***B*** | **S.E** | **Wald** | ***df*** | ***p*** | **Odds Ratio** | **95% CI for Odds Ratio** | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | **Lower** | **Upper** |
| *Saving water to help the environment* | | | | | | | | |
| Age | -0.003 | 0.062 | 0.002 | 1 | 0.968 | 0.997 | 0.883 | 1.127 |
| *Saving water to reduce bills* | | | | | | | | |
| Age | -0.028 | 0.059 | 0.233 | 1 | 0.629 | 0.972 | 0.867 | 1.090 |

To determine whether the type of housing tenure was associated with the willingness to buy and install water saving devices, a chi-square test for homogeneity was performed with the null hypothesis '$H_0$: the difference between the population proportions in individuals who own and individuals who rent is equal to 0' (see Table 5-3)[486], [487]. Two random samples of 198 participants were selected among individuals who own (group 1) and individuals who rent their property (group 2) included those who rent. In Group 1, 52.1% of the respondents reported that they would invest and install water saving devices, compared to 47.9% in Group 2, a non-statistically significant difference in proportions of .05, p= .584. Cramer's V (0.04) also suggested a small effect size [472]. Therefore, we fail to reject the null hypothesis. However, based on the odds ratio, the odds of investing in water saving devices are 1.17 times higher if individuals own their properties than if they rent [460].

Table 5-3. Summary of the statistical analysis for the 'demographics' variables (Ask Cardiff).

| Variables | Test | Sig. | Diff. Proportions |
|---|---|---|---|
| Age/Saving water to help the environment | Cochran-Armitage | 0.805 | N/A |
| Gender/ Saving water to help the environment | Chi-square for homogeneity | 0.315 | 0.07 |
| Type of property (owned or rented)/Willingness to buy and install water saving devices | Chi-square for homogeneity | 0.584 | N/A |

#### 5.1.2.2. Awareness of Water Usage and Attitudes Towards Water Conservation

To determine whether being aware of the amount used was associated to the feeling of doing enough to save water, a chi-square test of independence was conducted (see Table 5-4) [487], [492]. All expected cell frequencies were greater than five. There was a statistically significant association between the awareness of water used and the feeling of doing enough to save water $\chi^2(4) = 189.045$, $p<0.0005$. Cramer's V (.203) suggested a large effect size [472]. Therefore, we can reject the null hypothesis '$H_0$: 'Awareness of water used' and 'feeling of currently doing enough to save water' are independent' and accept the alternative hypothesis.

Similarly, a point-biserial correlation was run between the number of water saving devices owned by respondents and the feeling of currently doing enough to save water (see Table 5-4) [493]–[495]. Random samples of 50 participants for each group were selected. Group 1 refers to individuals who think they currently do enough to save water and Group 2 refers to those who think they currently do not do enough to save water. Data are mean ± standard deviation, unless otherwise stated. Preliminary analysis showed that there were (a) no outliers in the data, as assessed by inspection of a boxplot for values greater than 1.5 box-lengths from the edge of the box, (b) the number of devices was normally distributed for both Group 1 and Group 2, as assessed by visual inspection of Normal Q-Q Plots and (c) there was homogeneity of variances for the number of water saving devices owned for Group 1 and Group 2, as assessed by Levene's test for equality of variances ($p$ = .858). There was a statistically significant correlation between the feeling of doing enough to save water and the number of devices owned, $r_{pb}(98) = 0.247$, p= 0.013, with Group 1 owning more devices than Group 2 (1.2 ± 0.94 versus 0.7 ± 0.86). The feeling of currently doing enough to save water accounted for 6.1% of the variability in the number of devices owned and Cohen's $d = 0.55$ suggested a moderate effect size [472], [476].

To test whether individuals who save water for environmental reasons are more inclined to buy and install water saving devices than people who do not save water for such reasons, a chi-square test for homogeneity was performed (see Table 5-4) [486], [487]. Random samples of 50 participants who 'are motivated to save water to help the environment' and of 50 participants who 'are not motivated to save water to help the environment' were selected. Out of the 50 respondents who save water for environmental reasons, 16 (32%) would be willing to buy and install water-saving devices compared to 7 (14%) respondents among those who do not save water for environmental reasons, a statistically significant difference in proportions of 0.09, p=0.032. Cramer's V also suggested a small to moderate effect size (0.214) [472]. Therefore, we can reject the null hypothesis that states that the difference in proportions between the two groups in the population is 0 (zero) and accept the alternative hypothesis and affirm that the two proportions are not equal in the population.

Table 5-4. Summary of the statistical analysis for the 'awareness of water usage' variables.

| **Variables** | **Test** | **Sig.** | **df** | **Cramer's V** | **Variability/ Diff. Proportions** |
|---|---|---|---|---|---|
| Being aware of amount of water used/Feeling of currently doing enough to save water | Chi-square test of independence | <.0005 | 4 | 0.203 | N/A |
| Number of water saving devices owned/Feeling of currently doing enough to save water | Point-biserial correlation | 0.013 | N/A | N/A | 6.1% |
| Saving water to help environment/Willingness to buy and install water saving devices | Chi-square test for homogeneity | 0.032 | 1 | 0.214 | 0.09 |

#### 5.1.2.3. Financial Concerns

To understand whether knowing the price paid for water was associated with individuals' motivation to save water to reduce their bills, a chi-square test for association was conducted between these two variables (see Table 5-5). All expected cell frequencies were greater than five. There was a statistically significant association between the motivation to save water to reduce bills and knowing the price paid for water, $\chi^2(1) = 14.855$, $p < 0.0005$. However, the association between these two variables was weak, $\varphi = 0.081$, $p < 0.0005$.

Table 5-5. Summary of the statistical analysis for the 'financial concerns' variables.

| Variables | Test | Sig. | df | Cramer's V/Phi |
|---|---|---|---|---|
| Saving save water to reduce bills/Knowing the price paid for water | Chi-square test for association | < .0005 | 1 | 0.081 |

A binomial logistic regression was performed to ascertain the effects of being motivated to save water to reduce bills on the likelihood that participants invest and install water-saving devices (see Table 5-6) [488]. The logistic regression model was statistically significant, $\chi^2(2) = 35.082$, $p < .0005$. The Hosmer and Lemeshow test indicated that the model is not a poor fit ($p = 0.772$). The model explained 2.0% (Nagelkerke $R^2$) of the variance in the willingness to invest and install devices and correctly classified 68.6% of cases. Sensitivity was 100%, specificity was null, positive predictive value was 68.6% and negative predictive value was null. The motivation to save water to save bills, as a predictor variable of investing in water-saving devices, was statistically significant (p<0.005) (see Table 5-6). The odds ratio *Exp*(B) = 1.727, 95% CI = 1.437 to 2.076 suggests that individuals who save water to reduce their bills have 1.72 times higher odds to be willing to buy and install water saving devices.

In line with this, a binomial logistic regression was performed to ascertain the effects of knowing the price paid for water bills on the likelihood that participants invest and install water-saving devices (see Table 5-6) [488]. The logistic regression model was statistically significant, $\chi^2(1) = 0.450$, $p=0.502$. The model explained 0% (Nagelkerke $R^2$) of the variance in the willingness to invest and install devices and correctly classified 68.6% of cases. Sensitivity was null, specificity was 100%, positive predictive value was 68.8% and negative predictive value was null. knowing the price paid for water bills as a predictor variable was not statistically significant (see Table 5-6). The Hosmer and Lemeshow test indicated that the model was a poor fit ($p = 0.772$). However, the odds ratio *Exp*(B) = .918, 95% CI = 0.715 to 1.179 suggests that individuals who know the price of their bills are slightly less likely to be willing to buy and install water-saving devices.

Table 5-6. Summary of the binary regression analysis for 'financial concerns'.

| | ***B*** | **S.E** | **Wald** | ***df*** | ***p*** | **Odds Ratio** | **95% CI for Odds Ratio** | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | **Lower** | **Upper** |
| *Willingness to invest and install water saving devices* | | | | | | | | |
| Saving save water to reduce bills | .547 | .094 | 33.951 | 1 | .000 | 1.727 | 1.437 | 2.076 |
| Knowing the price paid for water | -.85 | .128 | .447 | 1 | .504 | .918 | .715 | 1.179 |

The Ask Cardiff survey (see Appendix A) gave insights regarding the practices, awareness and attitudes towards water conservation of a sample of Cardiff inhabitants. The results show that individuals are willing to save water, mostly to help the environment. It appeared that saving water to help the environment or to reduce the bills slightly increases the likelihood of investing in water-savings appliances. Yet, most of the respondents are reluctant to buy such devices and a large majority of them do not have any currently installed within their household. Most respondents also feel that they are currently doing enough to save water. This feeling is correlated with the number of water-saving appliances owned. Since the 'Ask Cardiff' survey reaches a large sample of individuals each year, it appeared useful to use this survey as a way to recruit participants for the more detailed WISDOM survey. Therefore, following a self-selection sampling method described in Chapter 4, respondents were asked if they wanted to be consulted again in the context of the WISDOM project, after completing the survey. Those who agreed were sent the WISDOM questionnaire (see Appendix B).

## 5.2. WISDOM Questionnaire

The WISDOM questionnaire (see Appendix B) was a more detailed questionnaire, sent to the 800 people who volunteered or opted-in to participate from the 'Ask Cardiff' survey (see Appendix A). As mentioned in Section 8.5.1, this lack of probability sampling can generate positive environmental bias in the responses obtained and limit the generalisation of the results obtained from the surveys. However, this non-probability sampling procedure is often used in qualitative research and, in the context of this project, provided access to a larger group of individuals [413], [449], [450].

This questionnaire was sent though emails as a link to the survey website between from November 2014 to December 2014. In total, 198 responses were collected. This questionnaire aimed at answering RQ1 and RQ2. The number of questions asked in the Ask Cardiff survey (Appendix A) was limited due to practical reasons. However, to expand on some of results that were obtained in the first survey, it was possible to include a wider set of questions in the WISDOM questionnaire (Appendix B). Therefore, this questionnaire contained forty multiple-choice and open questions divided in five different sections. As described in Section 5.2.1, the first part of the questionnaire focused on collecting demographic information about respondents' age, gender, level of education and employment status.

As individuals tend to think that they do enough to save water and are not willing to invest in water-saving devices, the WISDOM questionnaire (Appendix B) explored water-related behaviours more thoroughly. The second section of the questionnaire aimed at getting more detailed information about current households' properties and characteristics, including the water-using and water-saving devices implemented within their homes. It was then important to assess the performance of water-saving habits in households to test whether the feeling of currently doing enough to save water, as reported in the Ask Cardiff survey, was justified. To do this and to understand and determine the behavioural lifestyles that impact water usage, respondents were then asked to report some of their daily and weekly habits (Section 5.2.1.2).

Overall, participants to the Ask Cardiff survey also reported that they are motivated to save water, especially for environmental reasons. Thus, in the WISDOM questionnaire, the assessment of respondents' attitudes regarding their water usage was furthered through questions such as 'do you consider water conservation as an important issue?' or 'would you be willing to change some of your habits to consume water in a more sustainable way?' as mentioned in Section 5.2.1.3. Their willingness to invest in water devices was then assessed in Section 5.2.1.4.

Finally, as participants of the Ask Cardiff survey did not feel encouraged to save water by water companies, it was important to learn more about the relationship with their supplier. In the WISDOM questionnaire, the mean and frequency of communication between respondents and their water supplier were therefore reported, as mentioned in Section 5.2.1.5. This was important to get an overview of current interactions and communications tools used by water companies in the UK and to understand the impact that these companies have on their consumers' use of water.

### 5.2.1. Results

#### 5.2.1.1. Demographics & Household Characteristics

The first section of the questionnaire was focused on participants' demographics. Respondents appear to have some common characteristics and most of them can be described as middle aged, educated and employed persons. The proportion of men and women is relatively similar, with just a slight majority of men (56.6%). Respondents are mainly over 50 years old (55.56%) or between 31 and 50 years old (40.91%). Most of them have a high level of education as a third have a postgraduate qualification (33.3%) and have a university degree for a further 26.3%. Concerning their employment status, half of the participants are employed or self-employed (62.6%) and about a third are retired (31.3%). Only a minority of respondents are unemployed or studying (4%). Areas of Cardiff in which respondents live include Rhiwbina (8.6%), Canton (8.1%), Cyncoed (6.6%) and Llanishen (6.6%).

The second part of the survey was focused on household characteristics. It appears that the respondents are living either with one other adult (59.1%) or are the only adult of the household (29.5%). Only a minority of respondents are living with children under the age of twelve (12.9%) or with teenagers between 12 and 18 years old (7.6%). Semi-detached houses (34.85%) and terraced houses (33.84%) are the most common types of house followed by detached houses (19.70%). A large majority of the properties are owned (87.4%) and include a lawn or garden (79.3%).

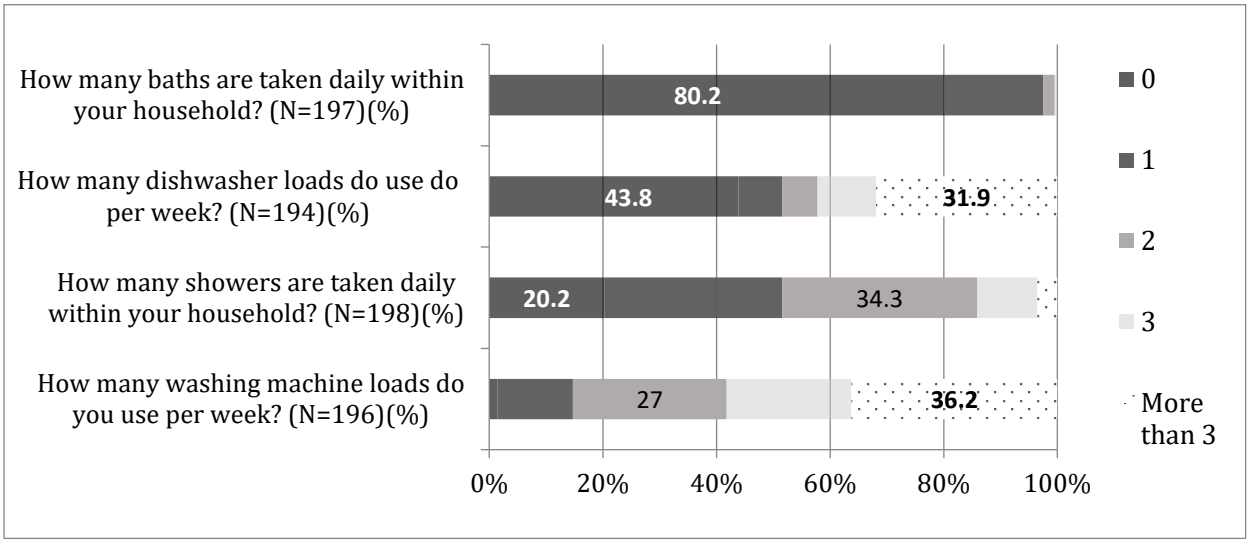
#### 5.2.1.2. Report of Domestic Consumption: Habits & Practices

This questionnaire helped determine what water devices are implemented within households around Cardiff. Most of the respondents report having an external tap (68.2%) and a dishwasher (61.6%). However, only a minority of households currently use water-saving devices. Indeed, a large majority of respondents do not owe greywater shower heat recovery (99.5%), solar water heating systems (99.5%), spray tap (96%), water-saving showerheads (83.8%) or thermostatic mixer taps (72.6%). The water-saving devices that are more commonly used are water meters (59.1%), dual flush toilets (58.6%) and rainwater harvesting solutions (31.8%). 93.4% of the respondents would use water-saving devices if they were provided for them.

Participants were then asked to assess the activities on which they use the most water on a daily basis. For a large majority of respondents, baths and showers are the activities requiring most water (82.8%), followed by toilet flushes (69.7%), washing machines (51%) and dishwashers (38.4%). However, most respondents report that no baths (77.3%) or only one bath (19.7%) are taken within their household on a daily basis. Showers are more commonly used as one (35.3%)

or two showers (36.5%) per household are usually taken daily. A minority of respondents affirm that no showers are taken daily (12.1%) or that up to three showers can be taken per day (11.6%). For the minority of respondents who reported having a thermostatic mixer tap (27.4%), which is a tap with inbuilt temperature settings, the usual temperature set is 37°C (31.25%) or 38°C (22.9%). The average number of toilet flushes per person within the household varies from three (17.7%) to four (17.2%) per day.

Other daily activities range from the use of washing machines (51.0%), dishwashers (38.4%) and water for drinking and cooking purposes (30.8%) (see Figure 5-6). Concerning dishwashers, respondents having this device use it seven times (18%), four times (12.3%), five times (12.3%) or just one time (12.3%) per week. However, most of them (43.8%) report doing no dishwasher load per week which suggest that they might use their dishwasher less frequently. Additionally, one (44%) or two (28.3%) sinks of water are usually filled daily for dishwashing by hand. Washing machines are used about two (25.6%) or three times (23.6%) a week for most respondents and are usually set to 40°C (59%) or to 30°C (30.3%). Tap water is rarely used for garden purposes in summer time as most participants affirm that they never use it on a weekly basis during that period (64%) while others tend to use it only once a week (20.2%). A third of respondents report using rainwater (50.5%), mainly to water their garden (86.1%).




*Weekly figures related to the number of showers and baths taken within the households were not available.

Figure 5-6. Repartition of daily and weekly domestic water-using activities within households.

### 5.2.1.3. Awareness of Water Usage and Attitudes towards Water Conservation

Regarding the awareness of water usage, half of respondents report that they do not know the amount of water used within their households (50.5%). Participants indeed check the amount of water they use at different frequencies. Only a few check it daily (3.5%), weekly (1%) or

monthly (7.6%) while most of them affirm checking it quarterly (32.3%), annually (48%) with a minority reporting that they never checked it (7.6%).

Most of the respondents have an initial interest in water conservation. A large majority of them consider water conservation as an important issue (92.4%) (see Figure 5-7). When asked about the importance they give to water conservation in their daily lives, most of them affirm that it is "important" or "very important" to them (71.7%). The main reasons found to encourage water conservation are to; "help the environment" (79.8%), "reduce wastage" (70.2%) and "reduce bills" (66.2%).

Basic water-saving habits already seem to be part of most of the respondents' daily life. A large majority of them try not to leave the tap running (83.3%) and make sure they do full loads of dishwashers and washing machines (80.3%). Regarding the duration of each shower, more than half of the participants take short showers (57.6%). This was verified by the fact that the average duration of a shower is approximately less than five minutes (24.7%) or five minutes (27.8%).

Some respondents consider that they are already doing enough to save water (40.9%) while other think they are not (39.4%) (see Figure 5-7). 67.2% however feel that they could do more to save water and are inclined to change some of their habits to consume water in a more sustainable way (86.87%) (see Figure 5-7). 47.5% would need tips and advice and a majority report that they currently do not feel encouraged to save water by water companies (75.3%) (see Figure 5-7).

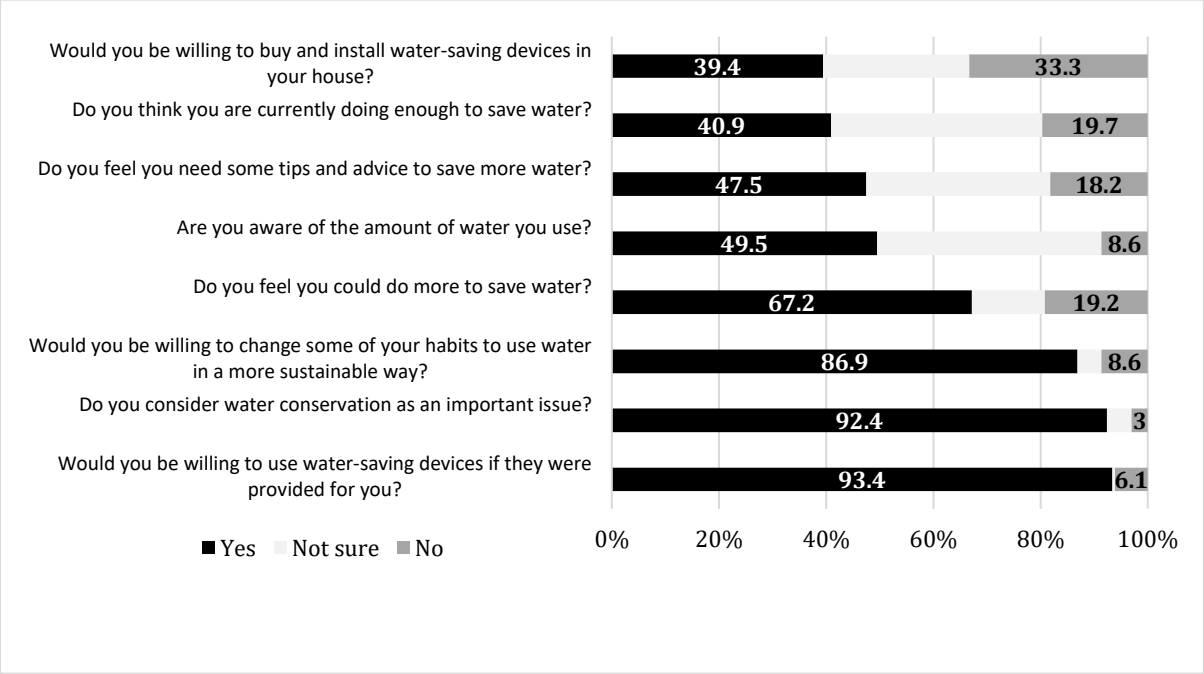



Figure 5-7. Participants' views of their own water consumption, the use of water-saving devices and water conservation.

#### 5.2.1.4. Financial Concerns

Overall, participants consider that water pricing should depend on the amount of water people use (74.2%) and, accordingly, that their water bill should depend on their consumption (80.8%). However, a quarter of the respondents are not sure of the price of their monthly water use (26.5%). Among these respondents, a majority would be more careful of their usage if they were aware of its costs (74.6%). Concerning the rest of the respondents, a quarter report that the amount of their monthly water bill is under £20 (9.50%), between £20 and £30 (25%), between £30 and £40 (16.50%), between £40 and £50 (10%) or over £50 (17%).

While 93.4% would use water-saving devices if they were provided for them, only 39.4% would be willing to buy and install these devices. Likewise, to a similar question "would you be willing to install a device to help you save water?" about a third of the participants respond that they would install it (35.4%) but the majority would do so only if the device was free (60.6%).

#### 5.2.1.5. Interaction with water supplier

Almost all respondents report having Dwr Cymru Welsh Water (DCWW) for water supplier (96%). The remaining percentage is not sure of their supplier. However, DCWW is the only supplier within this area of Wales and it can be assumed that all participants of the survey, as inhabitants of Cardiff, have this company as their water supplier [496].

71.1% of the respondents report interacting with their water company. However, most of them do it only rarely (55.3%) and only 2% report communicating often. For the rest of the respondents, this interaction happens a few times a year (13.7%). Overall, the reasons leading participants to communicate with their suppliers are to pay the bills (33.8%), to report a problem (22.2%) or to request information (13.1%). This is often done by mail (30.8%), by phone (27.8%) or online (25.8%).

Most respondents (75.3%) do not feel encouraged to save water by their water company. 76.8% are not receiving any regular updates from their supplier about their water usage or water services. Half of the respondents (52.5%) would however pay more attention to their water use if they were receiving more frequent updates about their consumption. Ideally, respondents would prefer receiving these updates by emails (83.3%), post (30.3%) or web (13.6%) and mobile (10.1%) applications. On another note, most of the respondents report never (48.5%) or only rarely (43.3%) checking their supplier's website. Thus, most of them are not sure of how to rate it (58.6%) while others consider it to be "average" (30.3%).

### 5.2.2. Analysis

To complement the descriptive analysis of the results, inferential analysis, including a variety of tests, were used to draw conclusions from the data [457], [1], [458].

#### 5.2.2.1. Demographics & Household Characteristics

Regarding the demographics of this survey, a Cochran-Armitage test of trend was first run to determine if there was a linear trend between age and the likelihood of considering water conservation as an important issue ( see Table 5-7) [490], [491]. The null hypothesis tested was '$H_0$: There is no linear trend in binomial proportions across age categories'. The age categories included were 18-30 (n=7), 31-50 (n=81), over 50 (n=110), and the proportions of respondents who considered water conservation as an important issue was .857, .901, .945, respectively. The Cochran-Armitage test of trend did not show a statistically significant linear trend between age and the likelihood of considering water conservation as an important issue ($p$ =.413). Therefore, we cannot reject the null hypothesis and cannot accept the alternative hypothesis. The odds ratio of considering water as an important issue in age 31 to 50 versus age 18 to 30 is 1.521 (95% CI, 0.162 to 14.276), 2.889 in age 50 and over versus age 18 to 30 (95% CI, 0.298 to 28.000), 1.900 in 50 and over versus age 31 to 50 (95% CI, 0.632 to 5.707). This shows that individuals are more likely to consider water conservation as an important issue as age increases.

The same test was run to determine whether a linear trend exists between the level of education and the proportion of participants who consider water conservation as an important issue (see Table 5-7) [490], [491]. The levels of education were 'secondary school' ($n$ = 19), 'six form/college/vocational training' ($n$ = 28), 'diploma' ($n$ = 12), 'advanced diploma' ($n$ = 13), 'university degree' ($n$ = 52), and 'postgraduate qualification' (n=66). The proportion of participants considering water conservation as an important issue was 0.889, 1.00, .904, 1.00, 1.00, and .968, respectively. The Cochran-Armitage test of trend did not show a statistically significant linear trend between the level of education and the proportion of participants considering water as an important issue, $p$ = 0.220. The odds ratio of considering water as an important issue in secondary/six form levels versus diploma/advanced diploma levels is 0.448 (95% CI = 0.47 to 4.239), 1,005 in University degrees/postgraduate levels versus secondary/six form levels (95% CI = 0.299 to 3.376), 0.450 in diploma/advanced diploma levels versus University degree/postgraduate levels (95% CI = 0.055 to 3.685). Individuals with diploma or advanced diploma are on average two times more likely to consider water conservation as an important issue than other individuals. Individuals with University degrees and postgraduate levels of education are only slightly more likely to consider it as an issue than individuals who have a secondary school or six form level of education.

Table 5-7. Summary of the statistical analysis for the 'demographics' variables (WISDOM).

| Variables | Test | Sig. |
|---|---|---|
| Age/Considering water conservation as an important issue | Cochran-Armitage | 0.413 |
| Level of Education/Considering water conservation as an important issue | Cochran-Armitage | 0.220 |

#### 5.2.2.2. Report of Domestic Consumption: Habits & Practices

The association between having a water meter and knowing the amount of water used was tested using the chi-square test for homogeneity (see Table 5-8) [486], [487]. 82 (70.1%) participants who had a meter knew how much water they use compared 16 (19.8%) participants among those who do not have a meter, a difference in proportions of .5. There was a statistically significant difference between the two independent binomial proportions ($p<0.001$). Cramer's V (.5) also suggested that the effect size was moderate [460], [472]. Based on the odds ratio, the odds of knowing the amount of water used is 9.75 times higher if individuals have a meter than if they do not [460]. Therefore, we can reject the null hypothesis stating that the difference between the population proportions in participants who have a water meter and those who do not is equal to 0 and accept the alternative hypothesis that states that not all group population proportions are equal.

Table 5-8. Summary of the statistical analysis for the 'domestic consumption' variables (WISDOM).

| Variables | Test | Sig. | Diff. Proportions |
|---|---|---|---|
| Having a water meter/Knowing the amount of water used | Chi-square test for homogeneity | <0.001 | 0.5 |

A linear regression was run to understand the effect of households' occupancy on the number of daily showers taken. To assess linearity, a scatterplot of occupancy was plotted against the number of showers taken, with superimposed regression line. Visual inspection of these two plots indicated that there was no linear relationship between the variables. Since this assumption was not verified, the linear regression analysis was not furthered. However, a crosstabulation analysis was performed (see Table 5-9). After visual inspection of the table, it is assumed, with caution, that there is no association between households' occupancy and the number or showers taken within households.

Table 5-9. Cross-tabulation between the number of showers taken and households' occupancy

| | | Households of 1 person | Households of 2 persons | Households of 3 persons | Households of 4 persons | Households of 5 persons | Total |
|---|---|---|---|---|---|---|---|
| Number of showers taken per day within households | 0 | 10 | 21 | 4 | 3 | 2 | 40 |
| | 1 | 16 | 28 | 6 | 8 | 0 | 58 |
| | 2 | 22 | 30 | 8 | 7 | 1 | 68 |
| | 3 | 4 | 9 | 4 | 2 | 1 | 20 |
| | 4 | 1 | 2 | 3 | 0 | 0 | 6 |
| | 5 | 0 | 1 | 0 | 0 | 0 | 1 |
| Total | | 53 | 91 | 25 | 20 | 4 | |

### 5.2.2.3. Awareness of Water Usage and Attitudes towards water Conservation

To determine whether the perception of water conservation as an important issue and the willingness to change some habits were associated, a chi-square test for association was run (see Table 5-10). However, while the assumptions for two categorical variables and for the independence of observations were met, the assumption of having expected cell frequencies greater than five was not met. A Fisher's Exact test was therefore conducted between these two variables. There was a statistically significant association between the perception of water conservation as an important issue and the willingness to change some habits, $p$ <0.001. Based on the odds ratio, the odds of being willing to change some habits are 10.476 times higher (95% CI, 3.401 to 32.269), if individuals consider water conservation as an important issue than if they do not [460].

This association between the perception of water conservation as an important issue and the willingness to buy and install water-saving devices was tested using the chi-square test for homogeneity (see Table 5-10) [486], [487]. 78 (42.6%) participants considering water conservation as an important issue were willing to buy and install water-saving devices compared to zero participants among those who do not consider water conservation as an important issue, a difference in proportions of 0.4, *p=0.001*. There was a statistically significant difference between the two independent binomial proportions (*p=0.001*). Additionally, Cramer's V (0.231) suggested a small effect size [472]. Therefore, we can reject the null hypothesis stating that the difference between the population proportions in participants considering water conservation as an important issue and those who do not consider this as an important issue is equal to 0 and accept the alternative hypothesis that states that not all group population proportions are equal.

Similarly, a point-biserial correlation was run between the number of water-saving habits performed by respondents and considering water conservation as an important issue [493]–[495]. Group 1 refers to individuals who consider water conservation as an important issue and Group 2 refers to those who do not think that water is an important issue (see Table 5-10). Data are mean ± standard deviation, unless otherwise stated. Preliminary analysis showed that there were (a) no outliers in the data, as assessed by inspection of a boxplot for values greater than 1.5 box-lengths from the edge of the box, (b) the number of devices was normally distributed for both Group 1 and Group 2, as assessed by visual inspection of Normal Q-Q Plots and (c) there was homogeneity of variances for the number of water saving devices owned for Group 1 and Group 2, as assessed by Levene's test for equality of variances ($p$=0.932). There was a statistically significant small correlation between considering water as an important issue and the number of water-saving habits performed, $r_{pb}(187) = 0.204$, p=0.005, with Group 1 owning more devices than Group 2 (2.35 ± 0.70 versus 1.75 ± 0.75). Considering water conservation as an important issue accounted for 4% of the variability in the number of water-saving habits performed. However, Cohen's $d$ (0.82) suggested a large effect size [472], [476].

Another point-biserial correlation was run between the number of water-saving habits performed by respondents and considering that one currently does enough to save water (see Table 5-10) [493]–[495]. Group 1 refers to individuals who consider they currently do enough to save water and Group 2 refers to those who do not consider that they currently do enough to save water. Data are mean ± standard deviation, unless otherwise stated. Preliminary analysis showed that there were (a) no outliers in the data, as assessed by inspection of a boxplot for values greater than 1.5 box-lengths from the edge of the box, (b) the number of devices was normally distributed for both Group 1 and Group 2, as assessed by visual inspection of Normal Q-Q Plots and (c) there was homogeneity of variances for the number of water saving devices owned for Group 1 and Group 2, as assessed by Levene's test for equality of variances ($p$ =0.767). There was no statistically significant correlation between the feeling of doing enough to save water and the number of water-saving habits performed, $r_{pb}(187) = 0.068$, p=0.364, with Group 1 performing more water-saving habits than Group 2 (2.38 ± 0.726 versus 2.28 ± 0.725). Feeling that one currently does enough to save water accounted for 0.5% of the variability in the number of water saving habits performed and Cohen's $d$ (0.14) suggested a small effect size [472], [476].

A chi-square test for association was conducted between feeling that one currently does enough to save water and being aware of the amount of water used. All expected cell frequencies were greater than five (see Table 5-10). There was a statistically significant association between the two variables, $\chi^2(1) = 6.634$, $p$ =0.010. However, this association was weak, $\varphi = 0.183$, $p$=0.010.

Finally, the association between feeling that one could do more to save water and feeling that one needs tips and advice to save more water was also tested using the chi-square test for homogeneity (see Table 5-10) [486], [487]. 73 (63.1%) participants considering that they could do more to save water felt that they need tips and advice to do so compared to 60 (69.9%) among those who do not feel that they need to do more to save water, a difference in proportions of 0.68, *p=0.003*. Cramer's V (0.06) also suggested a small effect size. Therefore, we can reject the null hypothesis stating that the difference between the population proportions in participants who feel they need to do more to save water and those who do not feel that way is equal to 0 and accept the alternative hypothesis that states that not all group population proportions are equal.

Table 5-10. Summary of the statistical analysis for the 'awareness of water usage' variables (WISDOM).

| **Variables** | **Test** | **Sig.** | **Effect size** (Cramer's V/Phi, Cohen's *d)* | **Diff. Proportions** |
|---|---|---|---|---|
| Considering water conservation as an important issue/Willingness to change some of your habits to consume water in a more sustainable water | Fisher's Exact test | <.001 | .341 | N/A |
| Considering water conservation as an important issue/Willingness to buy and install water-saving devices | Chi-square test for association | .001 | .231 | N/A |
| Considering water conservation as an important issue/Willingness to buy and install water-saving devices | Chi-square test for homogeneity | .001 | .231 | .4 |
| Considering water conservation as an important issue/Number of water-saving devices | Point-biserial correlation | .005 | .82 | N/A |
| Considering that one currently does enough to save water/ Number of water-saving devices | Point-biserial correlation | .364 | .14 | N/A |
| Considering that one currently does enough to save water/ Being aware of the amount of water used | Chi-square test for association | .010 | 0.183 | N/A |
| Feeling that one could do more to save water/Needing tips and advice to save more water | Chi-square test for homogeneity | .003 | .06 | .68 |

### 5.2.2.4. Financial Concerns

A chi-square test for association was conducted between saving water to reduce bills and believing that the water bill should depend on the amount of water used (see Table 5-11). All expected cell frequencies were greater than five. There was a statistically significant association between the two variables, $\chi^2(1) = 21.443$, $p < 0.001$. This association was moderate $\varphi = 0.329$, $p < 0.001$ [460], [472].

The same chi-square test for association was conducted between saving water to reduce bills and knowing how much one pays for its water consumption (see Table 5-11). All expected cell frequencies were greater than five. There was a statistically significant association between the two variables, $\chi^2(1) = 21.286$, $p < 0.001$. This association was also moderate, $\varphi = 0.328$, $p < 0.001$.

Table 5-11. Summary of the statistical analysis for the 'financial concerns' variables (WISDOM).

| **Variables** | **Test** | **Sig.** | **df** | **Effect size** (Cramer's V/Phi) |
|---|---|---|---|---|
| Saving water to reduce bills/Believing that the water bill should depend on the amount of water used | Chi-square test for association | <.001 | 1 | 0.329 |
| Saving save water to reduce bills/Knowing the price paid for water | Chi-square test for association | <.001 | 1 | 0.328 |

Goodman and Kruskal's λ was run to determine whether the willingness to buy and install water saving devices could be better predicted by the employment status of the participants [497], [498]. Goodman and Kruskal's λ was .017. There was a statistically significant 1.7% reduction in the error of prediction of the willingness to buy and install water saving devices when considering the employment status, $p$=.034. To further this analysis, it was found that the odds ratio of being willing to invest in water-saving devices in employed versus self-employed individuals is 1.222 (95% CI, 0.423 to 3.531), in employed versus retired individuals 1.571 (95% CI, 0.475 to 5.196), in employed individuals versus business owners 1.008 (95% CI, 0.531 to 1.913). This shows that employed individuals are more likely to be willing to invest in water-saving devices.

### 5.2.2.5. Interaction with Water Supplier

A chi-square test for association was run to determine whether the frequency of checking the water company's website and feeling encouraged to save water by the water company were associated (see Table 5-12). However, while the assumptions for two categorical variables and for the independence of observations were met, the assumption of having expected cell frequencies greater than five was not met. A Fisher's Exact test was therefore conducted between

these two variables. There was a statistically significant association between the two variables, $p$ = .008. Cramer's V (.213) also suggested a small to moderate effect size [472]. Based on the odds ratio, the odds of feeling encouraged to save water by water companies are 4.5 times higher (95% CI, 0.075 to 0.642), if individuals check the website often or a few times a year than if they check it rarely or never.

Similarly, a chi-square test for association was run to determine whether there was an association between the frequency of interaction with the water company and feeling encouraged to save water by the water company (see Table 5-12). All expected cell frequencies were greater than five. However, there was no statistically significant association between the frequency of interaction with the water company and feeling encouraged to save water by the water company $\chi^2(1) = .730$, $p$=.393. Cramer's V (.061) also suggested a small effect size [472]. Based on the odds ratio, the odds of feeling encouraged to save water by water companies are 1.4 times higher (95% CI, 1.129 to 1.287), if individuals interact often or a few times a year than if they check it rarely or never.

Table 5-12. Summary of the statistical analysis for the 'interaction with water supplier' variables (WISDOM).

| **Variables** | **Test** | **Sig.** | **df** | **Effect size** (Cramer's V) |
|---|---|---|---|---|
| Frequency of checking the water company's website/Feeling encouraged to save water by the water company | Fisher's Exact test | .008 | N/A | .213 |
| Frequency of interaction with the water company/Feeling encouraged to save water by the water company | Chi-square test for association | .393 | 1 | .61 |

The WISDOM questionnaire provided more in-depth information about individuals' domestic water habits, their awareness of their water usage and their level of preparedness and willingness to change their water consumption. A large majority of respondents consider water conservation as an important issue. This is associated with the willingness to change one's habits to save water and to invest in water-saving appliances. However, most of them do not seem to have any water-saving appliances installed within their houses and only a few are willing to invest in such devices. Additionally, only a minority of respondents frequently check the amount of water used by their household. Most respondents however appear to perform basic water-saving habits on a daily basis. Overall, they also tend to consider that they currently do enough to save water. This feeling is correlated with the awareness of the amount of water used, the number of water-saving habits

performed and the feeling that one could do more to save water. Finally, respondents do not feel encouraged to save water by water companies and only rarely interact with their supplier.

## 5.3. First Water Experts Consultation

In addition to the surveys carried out in the context of the project, an additional survey was conducted with water experts. The aim was to gather experts' views and personal opinions regarding the promotion of water conservation through behaviour change in Europe and in the UK. This provided a more global picture of current experts' views on the use of such method to promote domestic water conservation. It also informed answers to RQ1, RQ2, RQ3 and RQ4.

This questionnaire contained 30 questions divided into different sections. The first part of the questionnaire aimed at learning more about experts' domain of expertise, field of work and place of residence of the participants (Section 5.3.1). Depending on their country of residence, participants could reply to questions about current water consumption trends and ways to encourage behaviour change in Europe (Section 5.3.2.1) or in the UK (Section 5.3.2.2). In UK section, questions about water pricing were also added (Section 5.3.3). Moreover, as described in Section 5.3.4, experts were asked their opinions on peer pressure and the influence of subjective norms on people's behaviours regarding water consumption [7], [173], [179], [485]. Finally, questions related to the use of ICT to promote behaviour change were also answered (Section 5.3.5).

The questionnaire was sent by emails as a link to the survey. It was first distributed to the WISDOM Sig members, to members of Cardiff Water Research Institute and to water experts publishing in the field. As mentioned in Chapter 4, a snowball sample was then used; some water experts were targeted and asked to send the questionnaires to other experts they knew. In total, 34 responses were collected.

### 5.3.1. Demographics

A large majority of experts participating in the survey work in academia (76.5%) and a only a few report working in industry, consultancy, NGOs or as water providers (5.9%). Most respondents consider themselves as experts in the water domain (88.2%) while some of them are specialised in both water and energy issues (12.12%). Other domains of expertise included: "Bacteria that contaminate water causing infection and industrial problems", "building and building maintenance", "environmental psychology (especially energy, transport and climate change behaviours and perceptions)" and "economics", "smart cities" and "economic geography".

Respondents are mainly living in southern Europe (47.1%) and in the United-Kingdom (29.4%). The rest of them report living in Western Europe (17.6%), Northern Europe (2.9%) and in South America (2.9%).

### 5.3.2. Behaviour Change

#### 5.3.2.1. In Europe

Many experts (88.2%) believe that changing water users' behaviours is a solution to current water scarcity issues in developed countries. In line with the literature discussed in Section 2.1.2.1, they tend to think that the climatic conditions of a country influence people's awareness of water issues (61.8%). They also believe that European citizens do not have enough knowledge about water issues (70.6%), as mentioned in the Information Deficit Model in Section 2.2.7 [226]–[229]. Consequently, a large majority of them (94.1%) affirm that there is a need to change water users' behaviours in Europe and that encouraging domestic water-savings in Europe is important (93.9%).

According to the Information Deficit Model, the Value-Action Gap and the ABC Theory described in Section 2.2, a lack of knowledge of environmental issues and contextual barriers can limit behaviour change [16], [113], [170]. To encourage a change, the Rational Choice Theory also states that individuals need to be made aware of the costs and benefits of their actions and the Information Deficit Model that encourages the provision of more information to increase individuals' knowledge as mentioned in Section 2.2 [220]–[222], [226]–[229]. In line with this, experts were asked their opinions on the factors most likely to encourage and prevent behaviour change in Europe. In line with this, experts were asked their opinions on the factors most likely to encourage and prevent behaviour change in Europe.

According to experts, changing water users' behaviours in Europe and that encouraging domestic water-savings can be done by changing the policies and regulations at nationals and EU levels (58.8%) or by changing the water distribution and recycling infrastructure (52.9%). Half of them (50%) however consider that changing users' behaviours within their households is also efficient in encouraging water savings (see Figure 5-8). 82,4% believe that encouraging behaviour change can efficiently reduce water consumption.

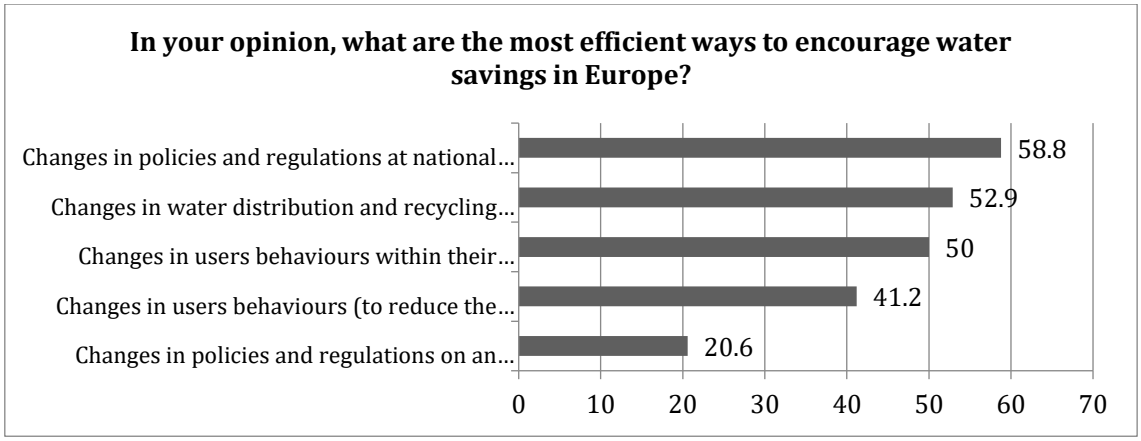



Figure 5-8. Experts' opinion on the most efficient ways to encourage water savings in Europe.

Most of them believe that behaviour change in Europe is however hindered by individuals' lack of knowledge about water issues (76.5%) and the lack of regulations and governmental initiatives (44.1%) (see Figure 5-9).

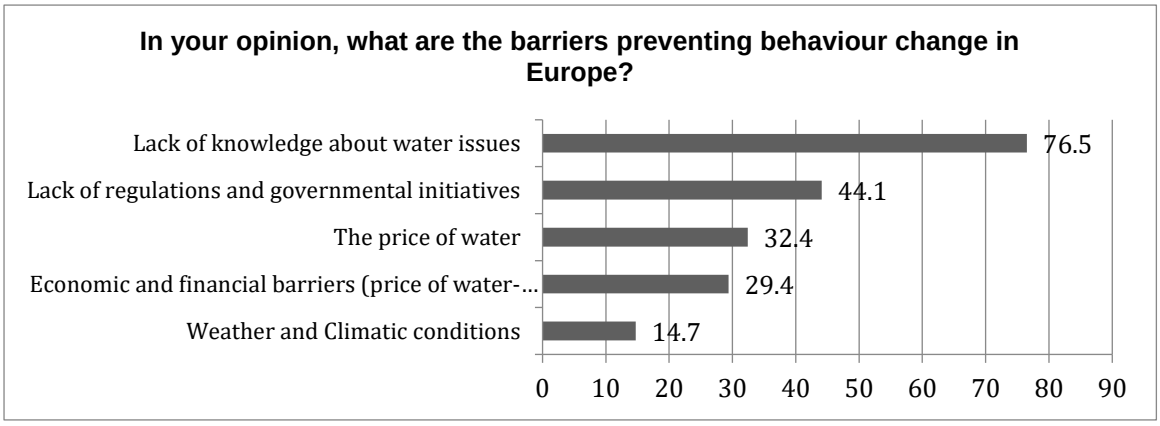



Figure 5-9. Experts' opinion on the barriers preventing behaviour change in Europe.

Other barriers preventing behaviour change in Europe include a '*lack of connection to environment*', a '*lack of understanding and interest*', '*social norms to over-consume*' and '*western and developed cultures which significantly affect adversely the use of virtual water to the detriment of water resources in some of the most water deprived countries in the world i.g. Egypt, Jordan*'.

Experts believe that the most efficient ways to trigger behaviour change and eco-friendly behaviours in Europe is through financial incentives, rewards and/or punishments (55.9%) or through information and education about the water used in the industrial or agricultural processes (50%) (see Figure 5-10).

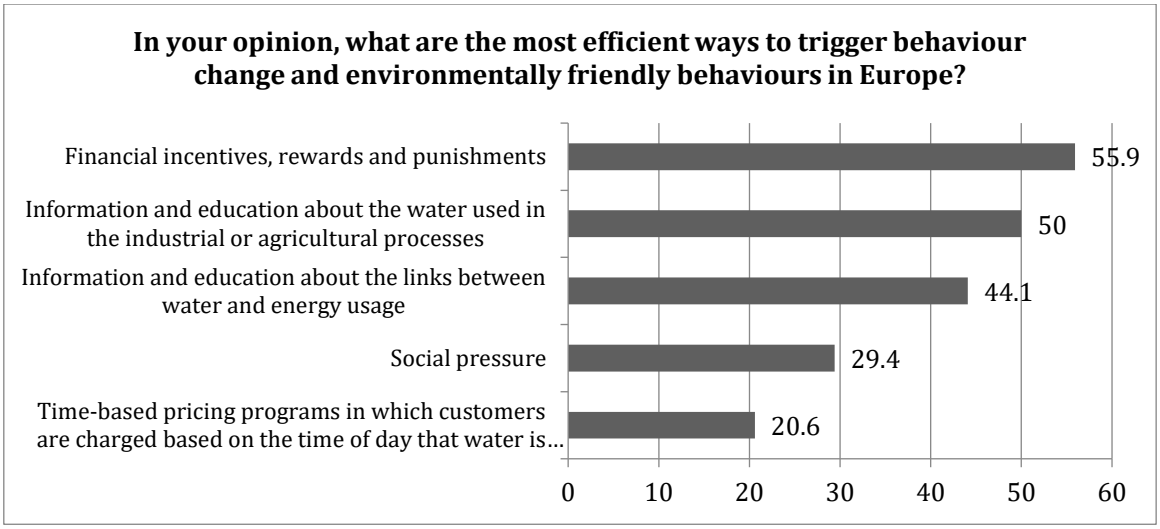


Figure 5-10. Experts' opinion on the most efficient ways to trigger behaviour change and environmentally friendly behaviour in Europe.

### 5.3.2.2. In the UK

Out of the twenty experts who replied to the questions related to water consumption in the UK, only 5% believe that UK citizens have enough knowledge about water issues. 90% affirm that there is a need to change water users' behaviours in the UK. They believe that encouraging behaviour change can efficiently reduce water consumption in this country (90.5%). Thus, a large majority (85.7%) also consider that it is important or very important to encourage domestic water savings. This can be done by changing users' behaviours at home (35.3%), changing policies and regulations on a national level (35.3%) and reducing users' consumption of virtual water (29.4%) (see Figure 5-11).

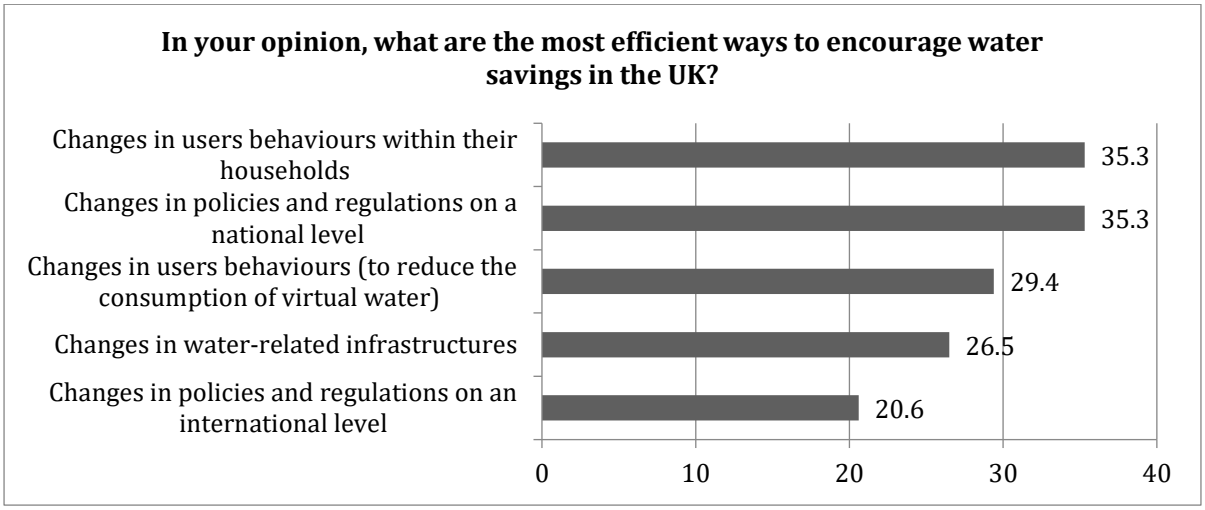


Figure 5-11. Experts' opinion on the most efficient ways to encourage water savings in the UK.

An expert adds that another way to encourage water savings in the UK is to "*change the culture of the demand for cotton, etc. Link clothing, etc. to the water footprint. Develop the water-food-energy nexus to include environment*".

According to these experts, lack of knowledge about water issues (50%) and the price of water (29.4%) are the main barriers preventing behaviour change in the UK (see Figure 5-12).

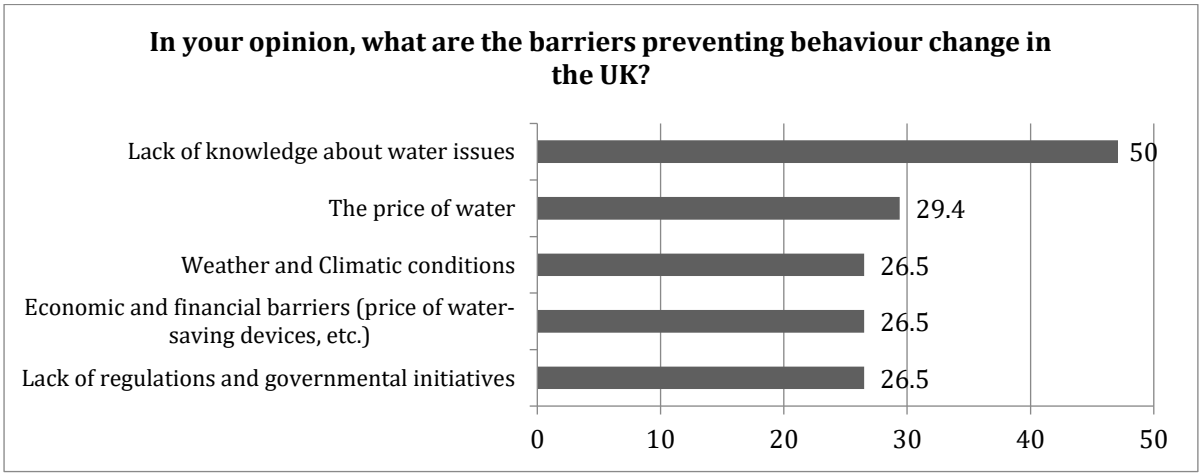



Figure 5-12. Experts' opinion on the barriers preventing behaviour change in the UK.

Other barriers identified by the experts include '*lack of interest and knowledge*' and '*lack of understanding of the water footprint and where the water comes from to produce clothes, etc – only often worn a couple of times due to changes in choice /fashion, etc*'.

Overall, experts consider that behaviour change and environmentally-friendly behaviours in the UK can be encouraged through information and education about environmental issues (41.2%) and about the links between water and energy usage (38.2%) (see Figure 5-13).

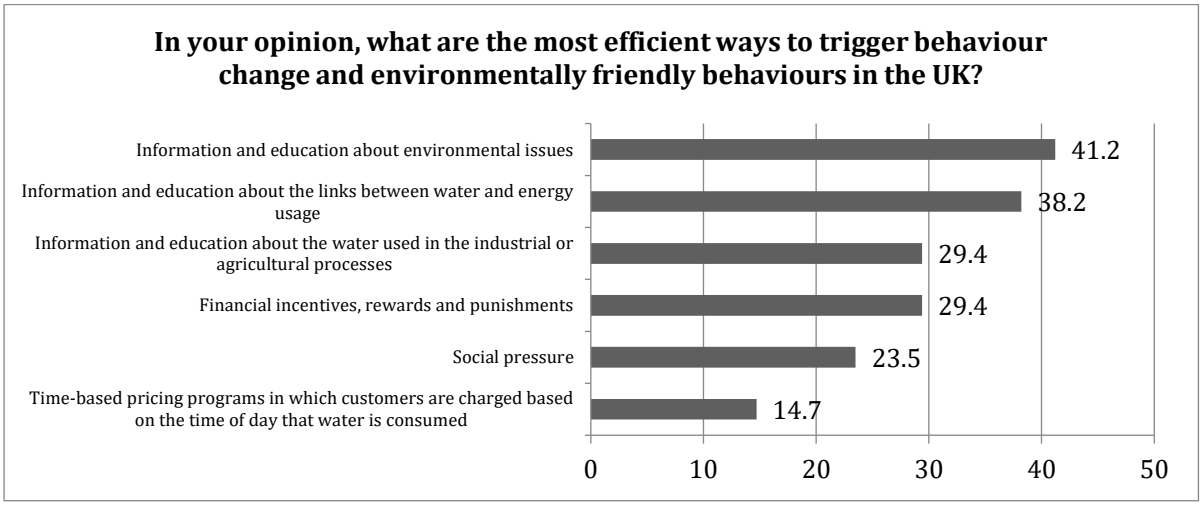



Figure 5-13. Experts' opinion on the most efficient ways to trigger behaviour change and environmentally friendly behaviour in the UK.

Other ways to trigger behaviour change and environmentally friendly behaviours in the UK include '*information on bills*', '*interaction with social groups*' and '*lecturing and meetings with key role models*'.

### 5.3.3. Financial Concerns

Regarding the price of water in the UK, experts think that it is neither expensive nor inexpensive (45%), inexpensive or slightly inexpensive (30%) or slightly expensive (25%). Their opinions are even more mitigated regarding dynamic pricing i.e. price of water varying depending on the time of the day, week and/or season. A number of them believe that dynamic pricing can be efficient in the UK (47.6%) while the rest neither agrees nor disagrees (33.3%) or disagrees (19.1%).

Similarly, only a minority of experts consider that time-based pricing programs defined as "programs in which customers are charged based on the time of day that water is consumed" are efficient in triggering behaviour change and environmentally-friendly behaviours in the UK (14.7%) and in Europe (20.6%). However, they consider that incentives, rewards and punishments in Europe (55.9%) and in the UK (29.4%) are slightly more effective in triggering behaviour change and environmentally-friendly behaviour.

### 5.3.4. Social Influence

A large majority of experts think that people are influenced by their peers when it comes to reducing their water consumption (see Figure 5-14).

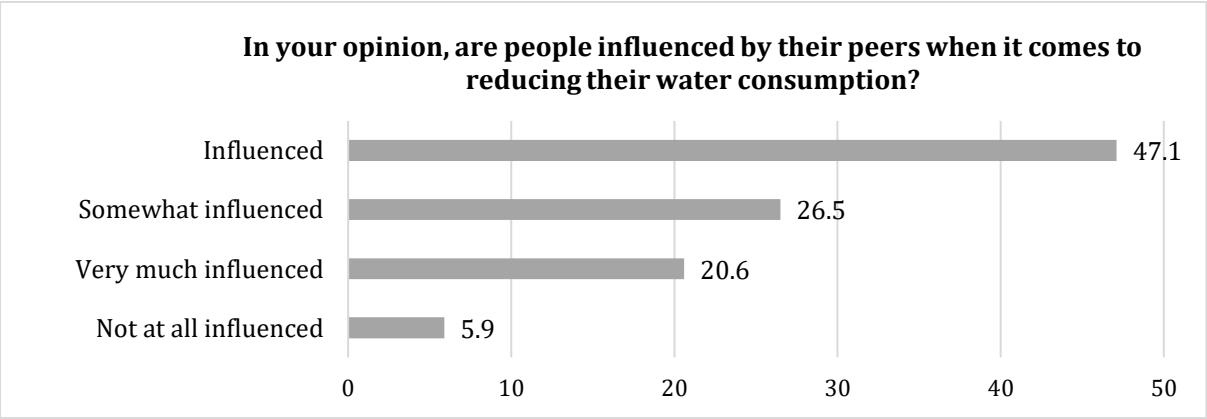



Figure 5-14. Social influence on water behaviours around the world.

### 5.3.5. Use of Information and Communication Technologies

A large majority of the experts state that using ICT, including in-home displays, mobile, web and tablet applications, can increase people's knowledge of their water usage (85.3%) and

encourage water savings (85.3%) and behaviour change (82.4%). According to them, in-home displays and applications on smart phones and tablets are equally efficient in promoting behaviour change and informing water users (see Figure 5-15).

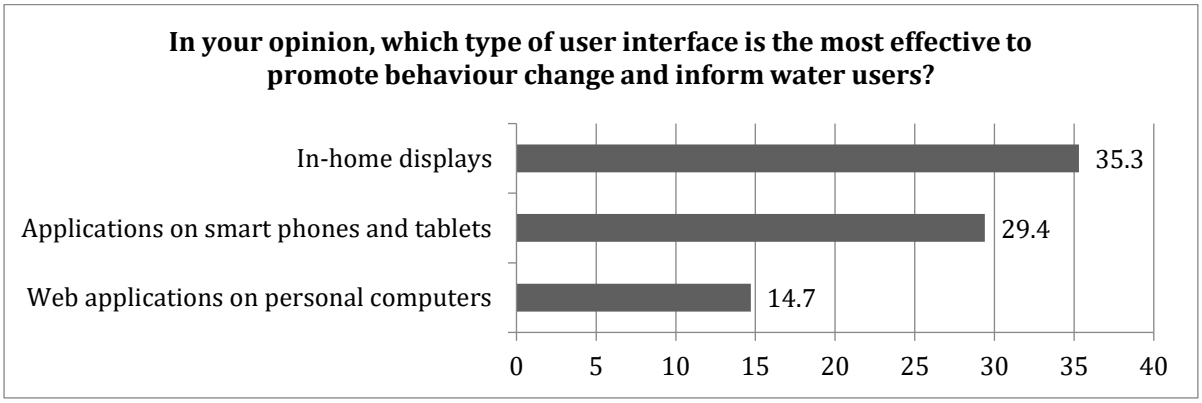



Figure 5-15. Experts' opinion on the most effective type of user interface to promote behaviour change and inform water users.

Other ways to promote behaviour change and inform water users are also suggested. They include "*alarms by SMS (e.g. for leakage detection)*", "*discussion with social group*", "*games for children in schools, information in towns, cities and rural areas*", "*information on water bills" and "delivering lectures on the topic to the right audience*".

This first experts' consultation demonstrated that there is a current need to change water behaviours in the UK. Experts believe that UK citizens do not have enough knowledge about water issues and that changing their behaviours within their households can encourage water savings. In their opinion, behaviour change in the UK is prevented by a lack of knowledge about water issues and by the price of water. Thus, information and education about environmental issues and about the links between water and energy usage can encourage behaviour change. More specifically, in-home displays and mobile and tablet applications are the most effective type of user interface to promote this change and inform users. Finally, experts report that individuals are influenced by their peers when it comes to saving water (see figure 5-14).

## 5.4. Structured Interview 1: Water Consultation

Prior to implementing the interface, Welsh Water (DCWW) sent a letter to its customers calling for volunteers to take part in a consultation on water consumption, as part of the WISDOM project (Appendix D). The questions included in the consultation were designed by the author, based on the literature and on the results of the initial surveys and experts' consultation (Appendix E). The list of questions was then transmitted to the Aqualogic interviewers who conducted the

consultation in the 25 volunteered households. This took the form of structured interviews in which one member of each household had to answer a specific set of questions. The aim of this consultation was to provide answers to RQ1, RQ2, RQ3 and RQ4.

The Ask Cardiff and WISDOM questionnaires (Appendixes A and B) showed that some individuals consider that they do enough to save water and that they do not need guidance to achieve water savings. In this structured interview, it was therefore important to identify current water-using domestic habits and practices to understand what individuals consider as 'doing enough' to save water. Through the interview, participants' habits and attitudes were therefore assessed. To answer OBJ1, OBJ2 and OBJ3, a review of water-consuming and water efficient devices implemented with households was established through the first set of questions. Moreover, in line with the literature described in Chapters 2 and 3, it was important to determine the participants' perceived self-identity, their intentions to save water and their feelings regarding social influence. To do so, a pro-environmental scale inspired by [187] and [11] and based on a reduced version of the New Environmental Paradigm (NEP) was used. The set of questions was adapted to environmental and water behaviours and included measures of pro-environmental self-identity and positive attitudes towards water conservation [187], [499], [500]. Participants were asked to assess a number of statements on a 5-point Likert scale ranging from 'strongly agree' to 'strongly disagree'. Similarly, it was crucial to collect baseline data about participants' knowledge of such issues. Therefore, a 6-point Likert scale was used to help participants assess their knowledge of water conservation and water issues. The perceived risk and perceived importance of water scarcity were evaluated as well, using a 4-point Likert scale.

Finally, to answer OBJ4, questions related to the use of laptops, electronic tablets or smart phones were asked to evaluate participants' current usage of new technology. Additionally, questions related to water prices in the UK were also included. This aimed at identifying people's opinions on the current prices and later assess their responsiveness to the financial features of the displays and their potential responses to pricing measures. It also brought additional elements of answer to OBJ3.

### 5.4.1. Results

#### 5.4.1.1. Demographics & Household Characteristics

The consultation was conducted from December 2015 to February 2016 in 25 households in Cardiff. While the respondents are predominantly males (72%), the age partitioning is even between those aged 21 to 35 (33%), 36 to 50 (33%) and over 50 years old (33%).

The respondents' households are principally composed of 2 (36%), 1 (32%) or 4 persons (16%). A large majority of households include only adults (72%) and only a minority report having a child (8%) or two children under 13 years old (16%) living in the house. Most respondents work full-time (68%). The rest are either retired (20%), working part-time (8%) or in full-time education (4%). As a result, households are mainly occupied outside work or school hours or on evening and weekends (56%). Only a third are occupied through the day (32%). Most of the houses are terraced (72%) or semi-detached (20%) houses. A large majority of houses were metered (96%).

76% of the houses do not have a front garden but 84% have a back garden. In the garden a few respondents report having a hose (36%) or a water butt (28%) but no sprinkler (0%), no pond (0%), swimming pool (0%) or hot tub (0%).

#### 5.4.1.2. Report of Domestic Consumption: Habits & Practices

A large majority of respondents report having efficient washing machines (96%). They do one or two (56%) or more than two full loads per week (44%). Most of them (77.3%) do not do any half loads. Concerning dishwashers, only 15 respondents have one at home and 46.7% of them affirm that it is an efficient type. 40% report not doing any full loads weekly while 20% do full loads up to 7 times a week. No half loads are ever done in these households.

The use of showers is preferred over the use of baths as a majority of respondents never (52.4%) or rarely (4.8%) take baths. Only 23.8% state that a bath is taken daily within their household. The vast majority of respondents (88%) spend between 5 and 10 minutes in the shower every day, on average, with a number of them using the shower for approximately 6 and 8 minutes (40%). Toilets are flushed 4 (24%), 6 (32%) or 8 times per day (20%) within the households.

Outdoor, out of the respondents owning a car, 87.5% report never washing it at home. Likewise, 77% of respondents never water their garden.

### 5.4.1.3. Awareness of Water Issues, Self-perception and Attitudes towards Water Conservation

In terms of relevant knowledge, while most of the respondents to the consultation feel that they have enough knowledge to make well-informed decisions about environmental issues (see Table 5-13), more than a third know too little or nothing at all about water conservation and water scarcity (32%) and only a few know these topics very well (12%)(see Table 5-13).

Table 5-13. Percentage and mean distribution of knowledge of issues (end users' consultation)

| **Items –** | **P** | **VW** | **QW** | **FW** | **TL** | **N** | **M** |
|---|---|---|---|---|---|---|---|
| 1. How much, if anything, would you say you know about climate change? | 0 | 28 | 40 | 16 | 16 | 0 | 3.20 |
| 2. How much, if anything, would you say you know about water scarcity/conservation? | 4 | 8 | 40 | 16 | 20 | 12 | 3.76 |
| Cronbach's Alpha: .742 | | | | | | | 3.48 |

P: Perfectly, VW: Very well, QW: Quite well, FW: Fairly well, TL: Too little, N: Not at all

Respondents also tend to believe that they will be personally affected by climate change (64%) more than by water scarcity (40%) (see Figure 5-16).

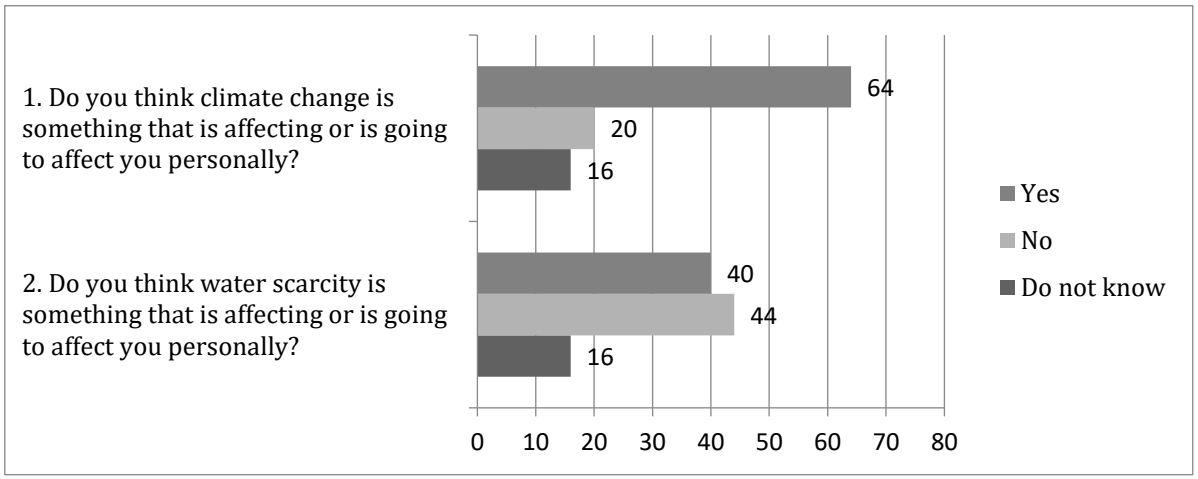



Figure 5-16. Beliefs about the effects of climate change and water scarcity.

Likewise, the number of respondents considering the issue of climate change as important or very important (88%) is higher than the number of respondents considering the issue of water scarcity as important or very important (64%) (see Table 5-14).

Table 5-14. Percentage and mean distribution of personal importance of issues (end users' consultation).

| **Items –** | **VI** | **I** | **SI** | **NI** | **M** |
|---|---|---|---|---|---|
| 1. How important is the issue of climate change to you personally? | 44 | 44 | 12 | 0 | 1.68 |
| 2. How important is the issue of water scarcity to you personally? | 36 | 32 | 16 | 16 | 2.12 |
| Cronbach's Alpha: .747 | | | | | 1.9 |

VI: Very important, I: Important, SI: Somewhat important, NI: Not important

Concerning the pro-environmental scale, mean scores were calculated to assess the pro-environmental values of the sample and the distribution of items responses was determined using frequency analysis [501].

Table 5-15. Percentage and grade point average of pro-environmental items (end users' consultation).

| **Items – Do you agree or disagree that** | **SA** | **A** | **NAD** | **D** | **SD** | **GPA** |
|---|---|---|---|---|---|---|
| 1. Making people more aware of how their behaviour affects the environment, water conservation encourages more environmentally-friendly behaviour | 60 | 32 | 0 | 8 | 0 | 4.44 |
| 2. People who care about the environment tend to reduce their water consumption | 60 | 36 | 0 | 4 | 0 | 4.52 |
| 3. Water savings should be mandatory | 32 | 52 | 8 | 8 | 0 | 4.08 |
| 4. Water conservation can help tackle climate change | 44 | 36 | 20 | 0 | 0 | 4.24 |
| 5. I am a person who endorses a green lifestyle | 12 | 52 | 36 | 0 | 0 | 3.76 |
| 6. I think of myself as someone who is very concerned with environmental issues | 24 | 44 | 28 | 4 | 0 | 3.88 |
| 7. Water Conservation is an important issue | 28 | 60 | 12 | 0 | 0 | 4.16 |
| 8. I would like to join and actively participate in an environmentalist group | 8 | 20 | 20 | 16 | 36 | 2.48 |
| 9. Whenever possible, I try to save natural resources | 52 | 40 | 4 | 4 | 0 | 4.4 |
| 10. I am the type of person that is careful about his/her water consumption | 44 | 52 | 0 | 4 | 0 | 4.36 |
| 11. I am the type of person who wants to save water | 52 | 40 | 4 | 4 | 0 | 4.4 |
| 12. I am not the type of person to use water carelessly | 68 | 28 | 0 | 4 | 0 | 4.6 |
| 13. Most people who are important to me want me to be environmentally friendly | 8 | 28 | 40 | 16 | 8 | 3.12 |
| 14. Most people who are important to me protect the environment | 12 | 32 | 36 | 20 | 0 | 3.36 |
| 15. I feel under social pressure to preserve the environment | 8 | 24 | 0 | 40 | 28 | 2.12 |
| 16. I feel I have enough knowledge to make well-informed decisions on environmental issues | 24 | 52 | 20 | 4 | 0 | 3.96 |
| Cronbach's Alpha: .809 | | | | | | 3.87 |

SA: Strongly agree, A: Agree, NAD: Neither agree nor disagree, D: Disagree, SD: Strongly disagree.

Responses to scale items were coded 1= Strongly disagree, 2= Disagree, 3= Neither agree nor disagree, 4= Agree and 5= Strongly agree [501], [502]. To assess the internal consistency of the pro-environmental scale, a test of reliability was conducted and a Cronbach's alpha value of 0.809

was obtained. This value shows a high level of internal consistency [503], [504]. The average pro-environmental score among the participants was 61.6.

#### 5.4.1.4. Social Influence

While they affirm that people who are important to them protect the environment (44%), responses to the pro-environmental scale show that 68% of respondents do not feel under social pressure to preserve the environment. Respondents are quite mixed when it comes assessing the views of their peers; 36% believe that people who are important to them want them to environmentally-friendly, 40% are unsure and 24% disagree with this statement. Additionally, for a large majority (84%), the views of their peers did not influence their decisions to take part in the consultation at all (see Table 5-16).

Table 5-16. Percentage and mean distribution of social influence items (end users' consultation).

| Item – | EI | VI | SI | SLI | NI | M |
|---|---|---|---|---|---|---|
| How much impact did the views of your family/friends/colleagues have on your decision to participate in this experiment and possibly reduce your water consumption? | 0 | 8 | 8 | 0 | 84 | 1.5 |

EI: Extremely influential, VI: Very influential, SI: Somewhat influential, SLI: Slightly influential, NI: Not at all influential

#### 5.4.1.5. Use of Information and Communication Technologies

As it can impact the use of the user-interface, it seemed important to assess participants' use of technologies. Respondents are relatively familiar (58%) or very familiar (28%) with the use of new technologies. Only one respondent report not being familiar with such technologies. A large majority of them also report having a computer at home (96%), a smart phone (96%) and a Wi-Fi connection (96%). Overall, participants are familiar with the use of laptops (84%), computers (100%), mobile applications (84%), web applications (60%), smart phones (92%) and electronic tablets (72%). However, mobile applications are the respondents' preferred way to view data (72%). Regarding social media, most respondents consider themselves as being very familiar (60%) or quite familiar (16%) with the use of such tools. 76% report using social media daily. However, most participants do not play online games either on phones or computers (80%).

Concerning the use of ICT applied to their water consumption, most of respondents would be willing to check a device that helps them reduce their consumption on a weekly (48%) or daily basis (36%). Likewise, they would like to receive updates about their consumption weekly (52%) or monthly (40%). A large majority of respondents (80%) would also be willing to invest in water-saving devices if they were not provided for them but more than half (56%) would not invest if there was no benefit in the short term.

### 5.4.2. Analysis

To further this descriptive analysis and reach conclusions, various statistical tests have been performed depending on the type of variable analyses [457], [1], [458].

#### 5.4.2.1. Report of Domestic Consumption: Habits & Practices

Concerning domestic water practices, a Spearman's rank-order correlation and a Somer's *d* were run to assess the relationship between the number of children occupying the household and daily use of baths within households. Preliminary analysis showed that the relationship was not monotonic, as assessed by visual inspection of a scatterplot. Therefore, the assumption of having monotonic relationship between the two variables was not met and neither the Spearman's rank order correlation or Somer's *d* test could be further performed. Similarly, a chi-square test for association was performed. However, the assumption of that all cells should have expected counts greater than five was not met and the test could not be further performed. Due to all these limitations, a crosstabulation analysis was performed (see Table 5-17).

Table 5-17. Use of baths compared to the number of children under 13 living in households

| | | Households with no child (under 13 years old) | Households with 1 child (under 13 years old) | Households with 2 children (under 13 years old) | Households with 3 children (under 13 years old) | Total |
|---|---|---|---|---|---|---|
| Bath usage | Once per day | 1 | 1 | 2 | 1 | 5 |
| | Twice per day | 1 | 0 | 1 | 0 | 2 |
| | A few times per week | 1 | 1 | 0 | 0 | 2 |
| | Rarely | 1 | 0 | 0 | 0 | 1 |
| | Never | 10 | 0 | 1 | 0 | 11 |
| Total | | 14 | 2 | 4 | 1 | |

After visual inspection of the table, there however seems to be an association between the number of children under 13 living in households and the number of baths taken. Indeed, 71.4% of the households that do not include children under 13 never take baths compared to only 2% of the households occupied by children. Only 7.1% of the households that do not include children under 13 take a bath daily against 57.1% of the households occupied by children. However, these results are to be interpreted with caution.

Similarly, a Pearson's product-moment correlation was run to assess the relationship between households' global occupancy and the number of showers taken within the households [505]. Preliminary analyses showed the relationship to be linear and monotonic. However, the variables

were not normally distributed, as assessed by Shapiro-Wilk's test ($p < .05$). A Spearman's rank-order correlation analysis, a non-parametric test, was therefore performed instead of a Pearsons' correlation [505]. There was a strong positive correlation between these two variables, $r_s(24) = 0.666$, $p<0.0005$. An increase in households' occupancy leads to an increase in the number of showers taken within households [505].

#### 5.4.2.2. Awareness of Water Issues, Self-perception and Attitudes towards Water Conservation

Somers' delta, known as Somers' *d* is a nonparametric measure of the strength and direction of association that exists between an ordinal dependent variable and an ordinal independent variable (see Table 5-18) [506], [507]. Somers' *d* was run to determine the association between 'I feel I have enough knowledge to make well-informed decisions' and the level of knowledge participants reported having on water scarcity issues [491], [506], [507]. There was a moderate, positive and significant correlation between the two variables ($d = 0.447$, $p=0.009$).

Table 5-18. Summary of the statistical analysis for self-reported knowledge and knowledge of water scarcity issues (end users' consultation).

| **Variables** | **Test** | ***d*** | **Sig.** |
|---|---|---|---|
| Feeling of having enough knowledge to make well-informed decisions'/Knowledge on water scarcity issues | Somers' D | .447 | .009 |

A binomial logistic regression was then performed to ascertain the effects of participants' pro-environmental values (pro-environmental score) on the likelihood that participants know very well about water scarcity and conservation issues (see Table 5-19) [488], [489]. Linearity of the continuous variables with respect to the logit of the dependent variable was assessed via the Box-Tidwell (1962) procedure. Based on this assessment, the continuous independent variables (pro-environmental score) was found to be linearly related to the logit of the dependent variable. There was no studentized residual. The logistic regression model was statistically significant, $\chi^2(1) = 10.278$, $p=0.001$. The model explained 64.8% (Nagelkerke $R^2$) of the variance in the likelihood to know very well about water scarcity and conservation and correctly classified 92% of cases. Sensitivity was 66.7%, specificity was 95.5%, positive predictive value was 66.7% and negative predictive value was 95.5%. The Hosmer and Lemeshow test indicated that the model was not a poor fit ($p =0.874$). Pro-environmental scores as predictor variable of knowing very well about water scarcity and conservation issues was not statistically significant (p=0.087). Yet, the odds ratio *Exp*(B) = 1.821, 95% CI = 0.916 to 3.622 suggests that for each unit increase in the

pro-environmental score, the odds of knowing very well about water scarcity and conservation issues increases by 1.821.

A binomial logistic regression was performed to ascertain the effects of participants' pro-environmental values (pro-environmental score) on the likelihood that participants consider water scarcity as an issue very important for them personally (see Table 5-19) [488], [489]. Linearity of the continuous variables with respect to the logit of the dependent variable was assessed via the Box-Tidwell (1962) procedure. Based on this assessment, the continuous independent variables (pro-environmental score) was found to be linearly related to the logit of the dependent variable. There was one studentized residual with a value of 3.086 standard deviations, which was kept in the analysis. The Hosmer and Lemeshow test indicated that the model was not a poor fit ($p$ =.722). The logistic regression model was statistically significant, $\chi^2(1) = 10.865$, $p$=.001. The model explained 48.3% (Nagelkerke $R^2$) of the variance in the likelihood of considering water scarcity as a very important personal issue and correctly classified 80% of cases. Sensitivity was 66.7%, specificity was 87.5%, positive predictive value was 75% and negative predictive value was 82.3%. Pro-environmental scores as predictor variable was statistically significant (p=.013) and odds ratio *Exp*(B) = 1.316, 95% CI = 1.059 to 1.634 suggests that the odds of considering water as an important issue increases as the pro-environmental score increases.

A binomial logistic regression was performed to ascertain the effects of participants' pro-environmental values (pro-environmental score) on the willingness to invest in water-saving devices if they were not provided (see Table 5-19) [488], [489]. Linearity of the continuous variables with respect to the logit of the dependent variable was assessed via the Box-Tidwell (1962) procedure. Based on this assessment, the continuous independent variables (pro-environmental score) was found to be linearly related to the logit of the dependent variable. There was one studentized residuals with respective values of -2.498 standard deviations, which was kept in the analysis. The logistic regression model was statistically significant, $\chi^2(1) = 11.701$, $p$=.001 and the Hosmer and Lemeshow test indicated that the model was not a poor fit ($p$ =.984). The model explained 74% (Nagelkerke $R^2$) of the variance in the willingness to invest and correctly classified 95.7% of cases. Sensitivity was 100%, specificity was 66.7%, positive predictive value was 95.2% and negative predictive value was 100%. Pro-environmental scores as predictor variable was not statistically significant (p=.151). The odds ratio *Exp*(B) = 1.955, 95% CI = 0.784 to 4.875 however suggests that as individuals' pro-environmental score increases, the willingness to invest in water-saving devices if they were not provided increases.

A binomial logistic regression was performed to ascertain the effects of participants' pro-environmental values (pro-environmental score) on the willingness to invest in water-saving devices if there were no short-term benefits (see Table 5-19) [488], [489]. Linearity of the continuous variables with respect to the logit of the dependent variable was assessed via the Box-Tidwell (1962) procedure. Based on this assessment, the continuous independent variables (pro-environmental score) was found to be linearly related to the logit of the dependent variable. There was no studentized residual. The logistic regression model was not statistically significant, $\chi^2(1) = 1.99$, $p$=.257 but the Hosmer and Lemeshow test indicated that the model was not a poor fit ($p$ =.149). The model explained 10.8% (Nagelkerke $R^2$) of the variance in the willingness to invest and correctly classified 64% of cases. Sensitivity was 12.5%, specificity was 88.2%, positive predictive value was 33.3% and negative predictive value was 68.2%. Pro-environmental scores as predictor variable of the willingness to invest if there were no short-term benefits was not statistically significant (p=.062). The odds ratio *Exp*(B) = 1.097, 95% CI = 0.958 to 1.256 suggests that as individuals' pro-environmental score increases, the willingness to invest in water-saving devices if there were no short-term benefits increases.

A binomial regression was performed to assess the effects of participants' pro-environmental values (pro-environmental score) on the willingness to check a device that would help reduce water consumption daily or more frequently (see Table 5-19) [488], [489]. Linearity of the continuous variables with respect to the logit of the dependent variable was assessed via the Box-Tidwell (1962) procedure. Based on this assessment, the continuous independent variables (pro-environmental score) was found to be linearly related to the logit of the dependent variable. There was no studentized residual. The logistic regression model was not statistically significant, $\chi^2(1) = .600$, $p$=.438 but the Hosmer and Lemeshow test however indicated that the model was not a poor fit ($p$ =.537). The model explained 3.2% (Nagelkerke $R^2$) of the variance in the willingness to check a device daily or more frequently and correctly classified 68.2% of cases. Sensitivity was 20%, specificity was 93.3%, positive predictive value was 66.7% and negative predictive value was 63.6%. Pro-environmental scores as predictor variable of the willingness to invest to check a device daily or more frequently was not statistically significant (p=.446). However, the odds ratio *Exp*(B) = 1.047, 95% CI = 0.930 to 1.179 suggests that as individuals' pro-environmental score increases, the willingness to check a device that would help reduce water consumption daily or more frequently increases.

Table 5-19. Summary of binomial regression analysis of the pro-environmental scores (end users' consultation).

| | ***B*** | **S.E** | **Wald** | ***df*** | ***p*** | **Odds Ratio** | **95% CI for Odds Ratio** | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | **Lower** | **Upper** |
| *Knowing very well about water scarcity/conservation issues* | | | | | | | | |
| Pro-environmental score | 0.600 | 0.351 | 2.922 | 1 | 0.087 | 1.821 | 0.916 | 3.622 |
| *Considering water scarcity as a very important personal issue.* | | | | | | | | |
| Pro-environmental score | 0.274 | 0.111 | 6.160 | 1 | 0.013 | 1.316 | 1.059 | 1.634 |
| *Willingness to invest in water-saving devices if they were not provided.* | | | | | | | | |
| Pro-environmental score | 0.670 | 0.466 | 2.067 | 1 | 0.151 | 1.955 | 0.784 | 4.875 |
| *Willingness to invest in water-saving devices if there were no short-term benefits* | | | | | | | | |
| Pro-environmental score | 0.092 | 0.069 | 1.785 | 1 | 0.181 | 1.097 | 0.958 | 1.256 |
| *Willingness to check a device that would help reduce water consumption daily or more frequently* | | | | | | | | |
| Pro-environmental score | 0.046 | 0.060 | 0.581 | 1 | 0.446 | 1.047 | 0.930 | 1.179 |

### 5.4.2.3. Social Influence

Somers' *d* was run to determine the association between participants' pro-environmental values (pro-environmental score) and the perceived influence of peers' views on the decision to participate in the experiment (see Table 5-20). There was a weak, negative correlation between the two variables, which was not statistically significant (*d* = -.168, *p*=.244).

Table 5-20. Summary of the statistical analysis for pro-environmental scores and perceived peer pressure (end users' consultation).

| **Variables** | **Test** | ***d*** | **Sig.** |
|---|---|---|---|
| Participants' pro-environmental values (Pro-environmental score)/Perceived influence of peers' views on the decision to participate in the experiment | Somers' D | -0.168 | 0.244 |

A binomial logistic regression was performed to ascertain the effects of participants' pro-environmental values (pro-environmental score) on the likelihood of considering peers' views as having no influence on the decision to participate in the experiment (see Table 5-21) [488], [489]. Linearity of the continuous variables with respect to the logit of the dependent variable was assessed via the Box-Tidwell (1962) procedure. Based on this assessment, the continuous independent variables (pro-environmental score) was found to be linearly related to the logit of the dependent variable. There was one studentized residual with a value of -2.479 standard deviations, which was kept in the analysis. The logistic regression model was not statistically significant, $\chi^2(1) = 0.045$, $p = 0.832$. However, the Hosmer and Lemeshow test indicated that the model was not a poor fit ($p = 0.615$). The model explained 0.3% (Nagelkerke $R^2$) of the variance in the willingness to check a device daily or more frequently and correctly classified 84% of cases. Sensitivity was 100%, specificity was null, positive predictive value was null and negative predictive value was 84%. Pro-environmental scores as predictor variable of considering peers' views as having no influence on the decision to participate in the experiment was not statistically significant (p=0.832)(see Table 5-21). The odds ratio *Exp*(B) = 0.984, 95% CI = 0.845 to 1.145 however suggests that as individuals' pro-environmental score increases, the likelihood of considering peers' views as having no influence on the decision to participate in the experiment decreases.

Table 5-21. Summary of binomial regression analysis of the pro-environmental scores and perceived peer influence (end users' consultation).

| | ***B*** | **S.E** | **Wald** | ***df*** | ***p*** | **Odds Ratio** | **95% CI for Odds Ratio** | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | **Lower** | **Upper** |
| *Considering peers' views as having no influence on the decision to participate in the experiment* | | | | | | | | |
| Pro-environmental score | -0.016 | 0.078 | 0.045 | 1 | 0.832 | 0.984 | 0.845 | 1.145 |

### 5.4.2.4. Use of Information and Communication Technologies

Somers' *d* was run to determine the association between the perceived level of difficulty of using the display and the frequency at which individuals would be willing to use the display amongst 10 participants (see Table 5-22). There was a weak positive correlation between these two variables. However, the result was not statistically significant ($d = 0.119$, $p < .378$).

Somers' *d* was also run to determine the association between being familiar with the use of new technologies and the frequency at which individuals would be willing to use the display among

25 participants (see Table 5-22). There was a weak negative correlation between the two variables (*d* =-0.279), meaning that as familiarity increases, the frequency at which individuals are willing to use the display decreases. However, this association was not statistically significant (p=0.071).

Finally, the same Somers' *d* test was run to determine the association between being familiar with the use of new technologies and the frequency at which individuals would be willing to receive updates about their consumption among 25 participants (see Table 5-22). There was a weak negative correlation between the two variables (*d* =-0.306), meaning that as familiarity increases, the frequency at which individuals are willing to receive updates decreases. However, this association was not statistically significant (p=0.059).

Table 5-22. Summary of the statistical analysis for the 'use of ICTs' variables (end users' consultation).

| **Variables** | **Test** | **Sig.** | ***d*** |
|---|---|---|---|
| Perceived level of difficulty of using the display/Frequency at which individuals would be willing to use the display | Somers' D | 0.378 | 0.119 |
| Being familiar with the use of new technologies/Frequency at which individuals would be willing to use the display | Somers' D | 0.071 | -0.279 |
| Being familiar with the use of new technologies/Frequency at which individuals would be willing to receive updates about their consumption | Somers' D | 0.059 | -0.306 |

The consultation conducted with end users in Cardiff households helped gain more detailed information about their awareness of water consumption and perceived attitudes towards water conservation and provided more practical knowledge as to individuals' level of preparedness for change. This consultation revealed that individuals consider themselves as eco-friendly persons and overall believe that they have knowledge about water scarcity and conservation. The average pro-environmental score (61.6) also shows that respondents have positive environmental attitudes which influence their perception of the importance of water conservation. A large majority of them are familiar with the use of new technologies and would be willing to invest in a device that informs them about their water consumption but only if it was providing short-term benefits. Concerning social influence, participants do not feel under social pressure to preserve the environment and did not feel pressured by their peers to take part in the experiment in the context of this project.

Following the action research process described in Chapter 4, the results from the first surveys have informed the design of the interface (described in Chapter 6) and brought initial insights to fulfil the four research objectives:

- OBJ1: Identify water users' current level of awareness of their water consumption and attitudes towards water usage.
- OBJ2: Assess the current level of preparedness for change among water users.
- OBJ3: Identify whether methods of encouraging behaviour change and water savings are most effective across consumers with differing views.
- OBJ4: Determine whether the use of near real-time user-orientated water feedback system promotes behaviour change and water conservation.

The main findings emerging from these results include:

- Partial awareness of the amount of water used within households.
- General interest in environmental issues.
- Perceived self-environmental identity and environmental knowledge.
- Basic water-efficient habits implemented in households.
- Willingness to save water and change habits.
- Limited number of water-saving devices implemented in households.
- Reluctance to invest in water-saving devices.
- Limited social influence, as perceived by respondents.
- Limited interaction with the water supplier.
- Frequent usage of new technologies.
- ICT can increase people's knowledge of their water usage, encourage water savings and behaviour change, according to experts.
- Preferred usage of mobile applications and in-home displays to provide water data.

Regarding OBJ1, on a demographic level, the population studied is in line with national statistics [58]. Trends in pro-environmental and water-saving attitudes also partly follow the literature on the subject [31], [64], [124], [129], [130], [133], [138], [139], [152]. Indeed, women, educated and employed individuals are more likely to demonstrate water-saving attitudes. The household occupancy and the house tenure also impact water behaviours and the investment in water-saving devices. Participants overall reported pro-environmental attitudes, beliefs and knowledge regarding water conservation. They largely consider water as an important issue and are careful about their consumption. Respondents to the water consultation also largely perceive themselves

as eco-friendly persons. In line with the Theory of Reasoned Action, the Theory of Planned Behaviour and the Cognitive Dissonance Theory, these positive self-identity and attitudes encourage water-saving behaviours. This was indeed reflected in the responses as participants reported performing eco-friendly habits at home. However, the awareness of domestic water consumption and knowledge of water issues are more limited in practice than expressed by individuals. Moreover, pro-environmental self-identity and attitudes only motivate water-saving actions to a certain extent. Thus, in terms of OBJ2, participants' level of preparedness to use water more sustainably indeed varies among respondents. While there is an apparent willingness to change habits to save water, individuals are reluctant to invest in water-saving devices. Regarding OBJ4, individuals are familiar with the use of new technologies and are able to use ICT. Finally, to address OBJ3, financial concerns and environmental matters were identified as most influencing people's engagement and motivation to save water. However, individuals do not feel under social pressure to reduce their consumption. Based on these results and to further the understanding of the impact of different behavioural strategies on individuals' attitudes and water consumption, it is crucial to include, test and validate different methods of encouraging behaviour change in the interface. These results will therefore inform the choice of behavioural strategies included in design of the user-interface, described in the following chapter. The impact of the interface will be determined through the trial phase of the project, results of which are reported in Chapter 7, in order to fulfil OBJ3 and OBJ4.

# Chapter 6: Phase 2: Design of the Interface

This chapter presents the theoretical framework underpinning the design of the user-interface, as influenced by Chapters 2 and 3. The review of theories in Chapter 2 helped to choose the psychological methods of behaviour change to implement in the design of the interface in order to promote water conservation. The complement this, Chapter 3 provided practical guidelines to better communicate these methods through the interface. These elements all informed the theoretical framework described in this chapter. In addition, the results of the initial surveys described in Chapter 5 are also considered to ensure that the strategies implemented in the interface are tailored to the population studied. Overall, the interface has been designed to efficiently increase users' awareness of their consumption and of water issues and to better encourage domestic water savings. More importantly, it aims at fulfilling OBJ3 by including and testing different methods of behaviour change that appeal to users' environmental interests (6.1.4, 6.2), financial interests (6.1.3) and social interests (6.1.2, 6.3). By implementing a combination of methods informed by best practice and key behaviour change theories, the author believes that the design and experimentation of this user-interface contributes to existing knowledge on the use of ICT to promote water conservation, as discussed in Chapters 8 and 9.

The interface has been designed to be primarily deployed on in-home displays (see image 6.1). It displays water consumption data stored within the WISDOM platform. WISDOM, in turn, collects this data from smart meters. These smart meters are attached to a wide-area network hosted by a base station on a nearby building. The smart meters transmit data at intervals to the base station, which transmits it via the internet to the WISDOM platform. The interface then fetches this data from the WISDOM platform. This process of data collection, and transmission has been conducted by partners of the WISDOM project who designed and installed the smart meter and WISDOM platform hardware/software.

Image 6.1. Picture of the interface deployed on in-home displays

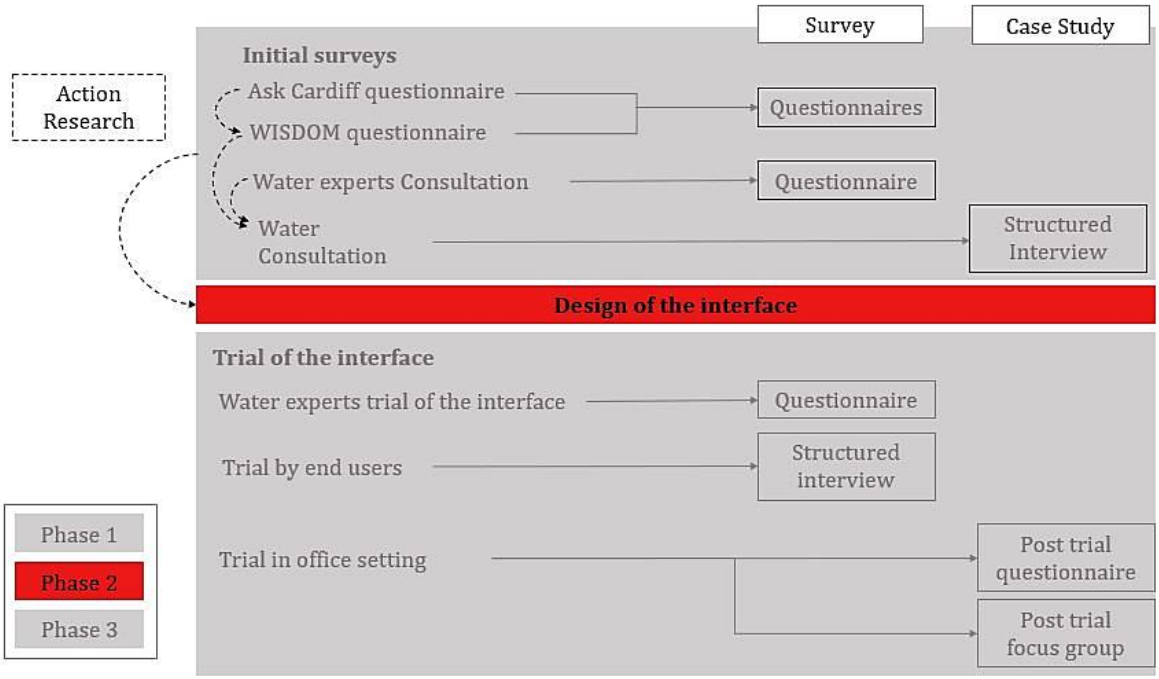



Figure 6-1. Focus of Chapter 6 (highlighted in red).

## 6.1. Designing an Efficient Interface

When designing and implementing a new technology, importance should be placed on the "perceived usefulness" and the "perceived ease-of-use" of a technology for consumers [481]. According to the Theory of Acceptance Model and the Diffusion of Innovation Theory (Section 2.3), the more useful and easy individuals think the technology is, the more individuals will be willing to use it [265], [481]. The technology should be personally beneficial to them and its use should be free of effort [176], [263], [482].

Other important factors to take into consideration are social pressure, people's willingness to cope with the inconveniences resulting from the adoption, i.e. the investment in the innovation, the lack of perceived risks regarding the functionality of the innovation [176]. Overall, the environmental, social and personal benefits of an innovation have to be communicated to encourage adoption [176], [266].

Considering these two theories, the user interface has been designed to be simple and easy to use. It includes;

- a home page,
- a 'my usage' tab
- a 'compare usage' tab.
- an 'about' and a 'contact' tab.

The homepage of the interface first offers an overview of the content of the display (see Figure 6-2).

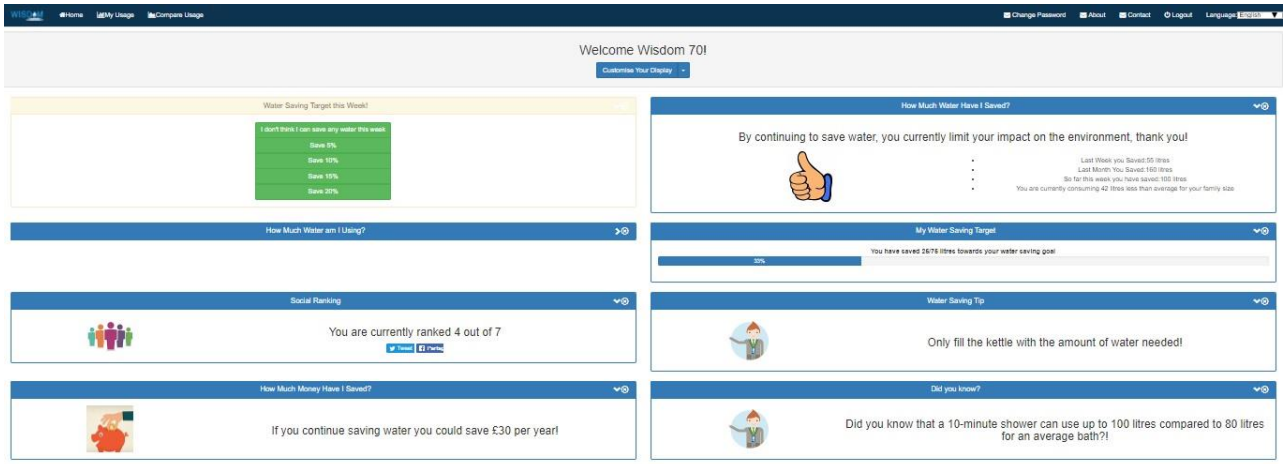



Figure 6-2. Homepage of the display.

As a visually attractive display is also more persuasive, the interface is designed to be clear and bright, with just a few colours [61], [332]. To increase its impact, the display combines text and simple diagrams [175]. As line graphs are useful to show changes over time, these charts are used to display participants' current and past consumption but also comparisons with other participant's consumption [339]. In addition, a pie chart is also used to display disaggregated data by appliances.

Additionally, the literature emphasizes the importance of providing individuals with tailored information [234], [235]. Additionally, setting preferences is a good way to maintain users' interaction with the display [175], [270]. Therefore, the interface offers users the possibility to personalize the content of this homepage by adding or removing boxes, depending on the type of information they prioritise (see Figure 6-3) [175], [270].

Figure 6-3. Customising the display.

Positive and encouraging messages are also transmitted to users on the homepage (see Figure 6-4). As affirmed by the Social Learning Theory (Section 2.2.9), it is important to congratulate and encourage users who are making efforts to reduce their consumption [223], [339]. Likewise, to prevent a potential 'boomerang effect' that could result in increased water consumption, it is important to send participants positive messages even when their water usage is above average [108], [330]. Instead of discouraging them, this indeed maintains their engagement in the interface and their motivation to save water [108], [186], [318].

The messages displayed on the interface include 'congratulations, you are helping the environment!' or 'reducing your consumption could help you reduce your water and energy bill!'. They are displayed on the homepage alongside a simple feedback in the form of an emoticon; 'thumb up' if users are reducing their consumption and 'thumb down' if they are increasing it [233].

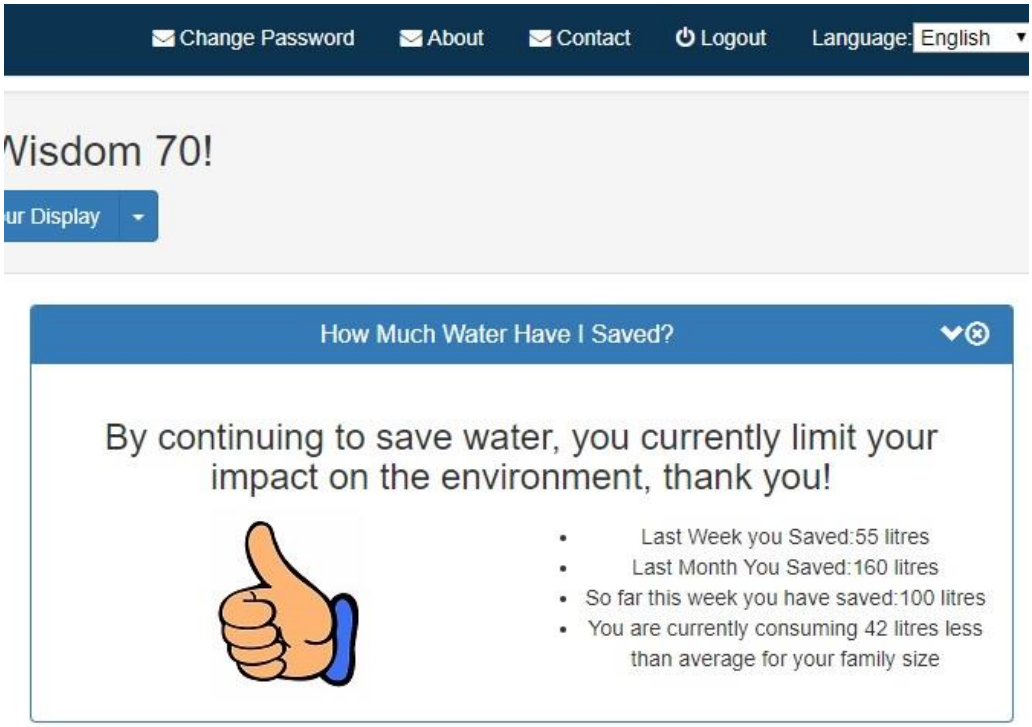



Figure 6-4. Emoticon and feedback messages on the homepage.

The trial of the interface by water experts and end users described in the following chapter aims at assessing the ease of use of the interface. As it can impact the results, the 'Technophilia scale' developed by [483] is used in these surveys to evaluate the participants' general use of technologies and measure their affinity for technology. Moreover, prior to testing the interface, participants are reminded that using the interface can help them reduce their water consumption and can have a positive impact on the environment and on their finances. The aim is to appeal to participant's values and needs whether they are economic, social or environmental in nature and highlight the perceived usefulness of this tool to counteract the reluctance to invest that was reported in the Chapter 5.

## 6.2. Evaluating and Stimulating Positive Environmental Attitudes

According to the Theory of Reasoned Action (Section 2.2.1), behaviours are directly influenced by intentions and indirectly influenced by attitudes and subjective norms [167], [170], [171]. Environmentally-friendly behaviours therefore result from an intention to positively change the environment [113]. It also requires individuals to evaluate the positive or negative the outcome of a behaviour based on material, social or psychological consequences and of the likelihood of this outcome [170], [171]. This then forms positive and negative attitudes towards the behaviour [170], [171]. Finally, subjective norms or the "perceptions that certain behaviours and attitudes are considered typical or desirable" within a community also impact behaviours

[167], [171], [174]. Individuals behave according to what they think is socially desired and want to give a positive image of themselves to members of their social group [175], [176].

The Theory of Planned Behaviour (Section 2.2.1) adds to the Theory of Reasoned Action and states that intentions to act pro-environmentally are also influenced by one's "own perceived competency" to perform a behaviour [177]. Individuals need to perceive that they have control over their behaviour and that they have the required skills and resources to perform it [7], [130], [172], [177], [183]–[185], [224], [225], [256]. Additionally, according the Attitude-Behavior-Context Theory (Section 2.2.2), behaviours are shaped by attitudinal variables such as beliefs, norms or values and by contextual factors such as monetary incentives and costs, physical capacities, social norms, institutional and legal factors [16], [113], [484]. The attitude-behaviour association is the strongest when contextual factors are neutral but is weak when the contextual forces are strongly positive or negative and either compel and prohibit a behaviour [113], [188]. For instance, if personal behaviours are difficult, time-consuming or expensive, their dependence on attitudinal factor is weak [113].

As described in the previous chapter, people's attitudes have been assessed through the initial surveys, using a pro-environmental scale based on the New Environmental Paradigm scale. Participants' attitudes towards water conservation are positive which suggests that their level of engagement in water-savings behaviours will be high [148], [219]. It is however important to reinforce these positive attitudes by educating users about the environmental benefits that can result from reductions in their water consumption [130], [170].

This is done on the homepage by using analogies to illustrate individuals' water savings and help them visualize the impact of their consumption [340]. As an example, people are informed that by saving over 80 litres of water in the past week, they save the equivalent of a full bathtub of water.

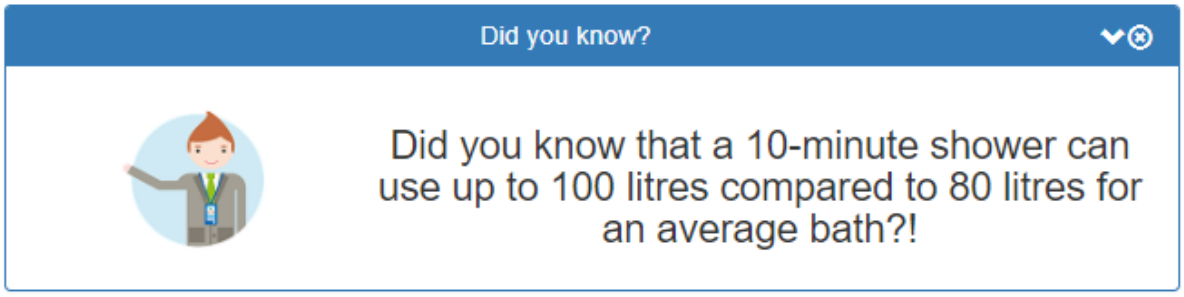



Figure 6-8. Daily facts displayed on the homepage of the interface.

Moreover, as indicated by the results of the Ask Cardiff and WISDOM surveys (Appendixes A and B), individuals are not always aware of the amount of water they use and check their water usage quarterly or annually. Feedback given directly after the performance of a water-saving or water-consuming action intends to encourage them to make the link between their actions and their environmental effects [104], [175]. Overall, continuous and frequent access to feedback also increases users' perception of individual control over their consumption [104], [175], [508]. On the 'my usage' tab, the interface therefore informs users about their water consumption on an hourly, daily, weekly, monthly or yearly basis (see Figure 6-12). They can choose the time intervals they prefer and are able to easily switch between these displays [90]. That way, users have a global idea of the evolution of their consumption on a long and short term [90]. They are also informed of their household's average and peak-time water consumption [91], [270], [322], [364]. According to the Information Deficit Model (Section 2.2.7), providing this information is crucial to prevent individuals from developing misconceptions about their consumption [39], [63], [127], [231].

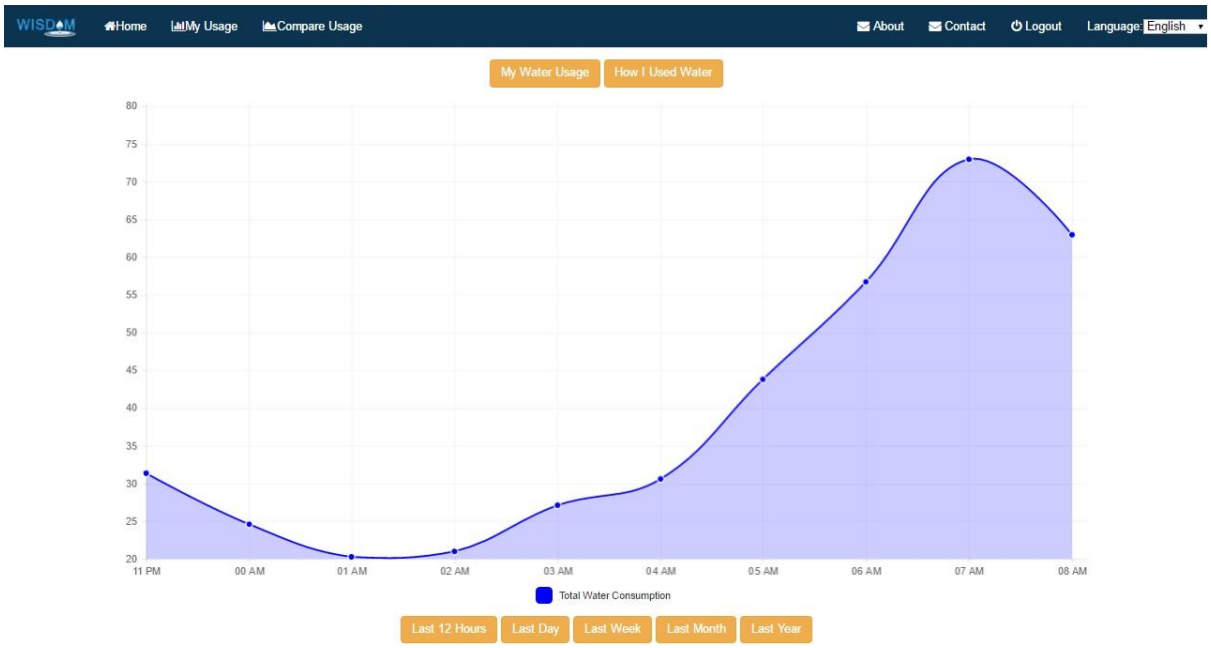



Figure 6-12. 'My usage' tab on the interface.

More specifically, a breakdown by appliances also allows users to target the devices that use the most water within their household (see Figure 6-13) [53], [90], [318], [332], [366], [379]. Thus, users can concentrate their conservation efforts by reducing their consumption on specific devices and during specific activities, as demonstrated in the literature [270], [318], [379]. It is also easier for them to spot leaks.

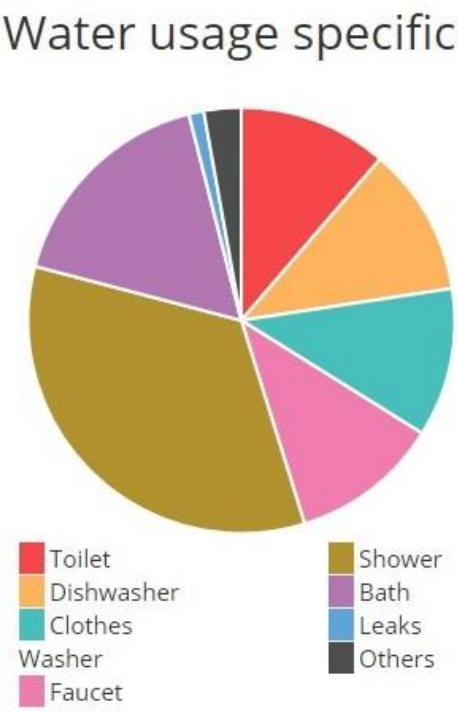



Figure 6-13. Mock-up of disaggregated data displayed on the interface.

The trial phase described in the following chapter aims to determine whether people feel that they have more control and opportunities to reduce their consumption after using the user-interface.

## 6.3. Understanding and Modifying Habits and Behaviours

As discussed in Section 2.2.2, according to Triandis' Theory of Interpersonal Behaviour, habits limit the predictive power of intentions and attitudes on behaviours [115], [189], [191]. Likewise, the Attitude-Behavior-Context Theory (ABC Theory), states that habits and routine should be considered as causal variables predicting behaviours.

However, it is possible to encourage the formation of new habits. A behaviour becomes stable after 18 to 254 days depending its complexity [193]. It takes more time for complex tasks to become automatic than it takes for simple tasks [193]. The difficulty of changing water behaviours depends on the degree of personal sacrifice it requires. This varies depending on the actions performed, i.e. turning off the tap when brushing teeth, require limited personal sacrifice, compared to. reducing the number of baths and showers taken within a household [48]. People will more easily adopt green behaviours if they do not have to compromise their quality of life [176]. The easier a behaviour is to adopt, the more people feel in control and adopt it [176]. The Self-Perception Theory (Section 2.2.8) also states that reminding people of environmental past

actions can influence their environmental self-identity and therefore environmental actions [195].

Surveys described in Chapter 5 gave an overview of participants' current water habits and provided detailed information about the water devices implemented in households and the frequency of their usage. This showed that most respondents feel that they already do enough to save water. Yet, only a minority have water-saving devices and some of them need guidance to help them save water. This suggests that individuals might be unaware of ways to further reduce their consumption. The efficiency of feedback can thus be limited if users do not know what to do about their consumption [175]. Moreover, the difficulty of changing water behaviours depends on the degree of personal sacrifice required and on the actions performed [48]. The easier a behaviour is to adopt, the more people feel in control and adopt it [176]. Based on this knowledge, the user-interface aims at changing these water habits by suggesting easy and tailored water-saving activities to perform and by providing tips and advice to ease the development of these new activities [210], [332]. On the homepage, new tips and advice are displayed every day on the homepage to guide participants in reducing their consumption (see Figure 6-9). They give examples of daily water-saving actions that are easy to perform. These include 'toothpaste works better when it's dry, so you only need water when rinsing your teeth' or 'put the plug in the bath before turning on the tap'.

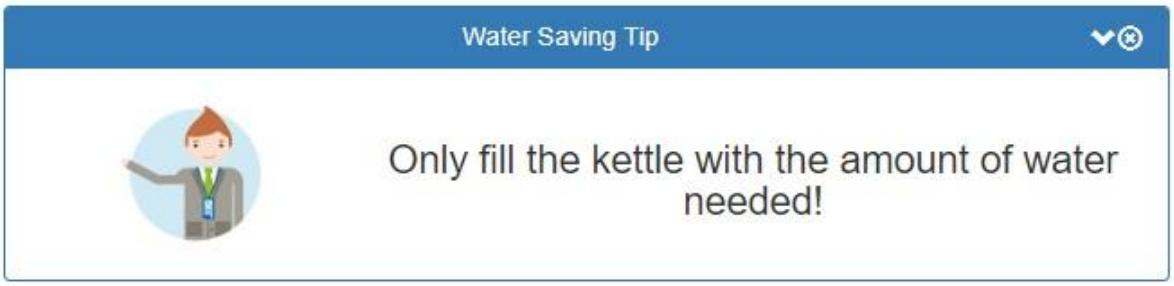



Figure 6-9. Daily tips displayed on the homepage of the interface.

Moreover, in line with community-based social marketing methods (Section 3.1.2), combining feedback with goal setting is a good way to encourage water savings [90], [108], [175], [318], [333], [339], [340]. By being able to set goals for themselves, motivation to reduce water consumption comes from the users themselves and not from exterior factors [90]. Thus, on the homepage, users have the possibility to choose a water-saving target every week from a predefined set of targets ranging from a '5%' reduction to a '20%' reduction (see Figure 6-10).

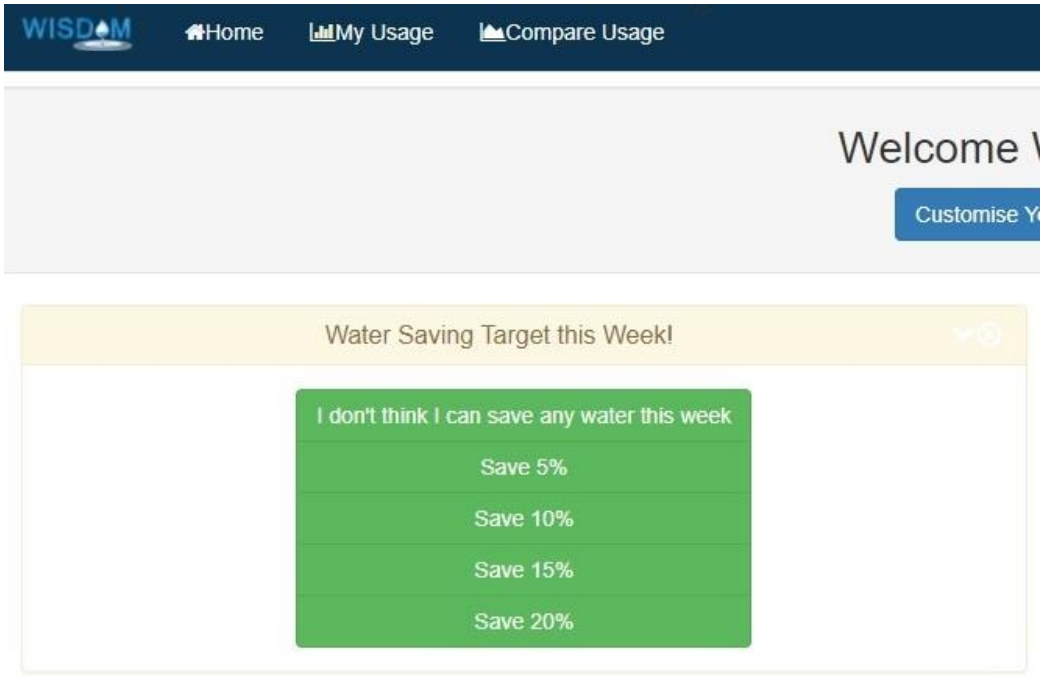



Figure 6-10. Weekly water saving targets.

They can also see their progression towards their weekly water saving target (see Figure 6-11).

Figure 6-11. Water saving target progression bar.

The potential impact of the user-interface on habits is tested during the trial phase but also through the structured interviews and focus group described in the following chapter.

## 6.4. Activating Norms and Values

According to the Value Theory (Section 2.2.3), individuals have self-transcendent and self-enhancement values [196], [198]. Sustainable consumption sometimes pits individual interests against what benefits others, nature and the environment [88]. They engage in sustainable actions depending on how they classify and prioritize their values [88], [196], [199]. However, sustainable consumption is often costly, effortful and require sacrificing one's comfort [88]. This can hinder the fulfilment of self-transcendent values, especially if people do not to exercise self-control to act in line with those values [88]. Environmental action can also be motivated by

egoistic and hedonic concerns such as the desire to save money, to gain social approval, to earn rewards or to avoid punishments [113], [206], [214]. According to the Rational Choice Theory (Section 2.2.6), individuals estimate the costs and benefits of their actions and choose to act according to the choice that bring them the greatest satisfaction [220]–[222]. Therefore, they need to receive enough information about the environmental costs and benefits of their actions to make well-informed decisions [120].

According to the Value Action Gap (Section 2.2.3), one of three barriers preventing people to act in accordance with their values is individuality i.e. attitudes and temperament [312]. The two other main barriers include the lack of responsibility to take action and to feel like one can be useful and practicability, including social and institutional constraints [130], [209]. Similarly to values, the Norm Activation Model, the Value-Belief-Norm Theory and the Model of Responsible Environmental (Section 2.2.4 and Section 2.2.7) state that, to activate personal norms, people have to be aware of the consequences of their actions on the welfare of others and take responsibility for these consequences [130], [171], [224], [225]. They therefore need to evaluate environmentally behaviours according to their positive or negative consequences [171], [218]. Activated personal norms participate in developing feelings of moral and personal obligation that guides a behaviour [113], [171], [217]. Individuals with biospheric values know that their behaviour can have negative environmental consequences and tend to feel responsible for environmental problems [88]. This increases their sense of moral obligation, leads to the activation of their personal norms and encourages their engagement in environmental behaviours [88], [215]. Likewise, altruistic persons caring for other people, people who value other species are concerned by environmental threats affecting them and act to preserve them [113]. Thus, increasing individual's awareness of current environmental issues and making them aware of the impact of their consumption can promote water savings [173], [323].

Through their responses to the initial surveys described in Chapter 5, participants demonstrated both self-enhancement and self-transcendent tendencies. Yet, to encourage sustainable actions, it is important to strengthen their self-transcendent values but also to target different values simultaneously through situational cues [88]. Therefore, in addition to appealing to biospheric and altruistic values through environmental information, the interface also considers egoistic and hedonic values through financial information. As stated in the Rational Choice Theory, financial concerns often guide people's actions. Considering this, it is therefore important to take into consideration these financial interests and show consumers the money that they can potentially save by reducing their water consumption (see Figure 6-7) [90]. This can also increase users' engagement in water saving activities [233].

Moreover, showing individuals the financial savings they could achieve by reducing their consumption in the long term, over a year for instance, can help them maintaining the performance of water-saving habits [355]. Estimating potential yearly savings also make it possible to display more significant financial savings and trick consumers into thinking that they can save a larger amount of money [355]. This is particularly important in the UK where the price of water is as low as just over £1 per day might not be enough to motivate individuals to reduce their consumption [44], [47]. In line with this, to have more impact on individuals' water consumption, the financial savings displayed on the interface are estimations of savings that could be achieved over a long period of time.

Figure 6-7. Financial savings displayed on the home page.

The user-interface shows participants the impact of their water consumption on the environment and on their finances. The impact of these features on participants' behaviours and values is assessed though the final questionnaires, structured interviews and focus group, described in the following chapter.

## 6.5. Informing and Increasing Knowledge

According to the Information Deficit Model (Section 2.2.7), there is a deficit in public knowledge and in the understanding of environmental issues [226]–[229]. Yet, according to the Model of Responsible Environmental Behaviour (Section 2.2.7), individuals' intentions are influenced by individuals' knowledge of environmental issues and of relevant action strategies [224], [225]. Thus, this apparent lack of knowledge hinders behaviour change and public involvement in pro-environmental behaviours and leads to misconceptions regarding resources consumption [39], [63], [127], [130], [228], [230], [231]. Regarding water usage, it is particularly difficult for individuals to be aware of the amount of water used in their household, due to invisible pipes and flows [39], [63].

In line with this, half of the experts affirm that UK citizens do not have enough knowledge about water issues. They therefore believe information and education about environmental issues can encourage behaviour change[226]–[229]. The Model of Responsible Environmental Behaviour (Section 2.2.7) states that individuals' knowledge of environmental issues and of relevant action strategies influence their intentions to act [224], [225].

On its homepage, the interface therefore provides daily environmental facts to increase users' awareness of their consumption and improve their knowledge of current environmental issues. These include facts such as 'did you know that the UK has less water than many countries on the Mediterranean Coast?'. More specifically, as suggested by experts and as discussed in Section 3.2.1, informing users about the consumption of virtual water increases their awareness of their water consumption and leads them to develop more sustainable habits [350]. Thus, this type of information has also been included in the daily facts: 'did you know that the production of a cotton t-shirt requires the equivalent of 25 full baths of water?' or 'did you know that 4500 litres of water are used to produce a 300g beef steak, 2500 litres to produce 500g of cheese and 1000 litres to produce one litre of milk? This is called 'virtual water' or the 'water footprint'. Similarly, experts indicated that information about the links between water and energy usage could also encourage behaviour change. As mentioned in Section 3.2.1.3, some people are indeed more interested in their energy consumption than in their water consumption [323]. For these persons, information about the energy consumption of the household and its link with water consumption are therefore more effective in promoting water savings [86], [270], [323]. This is done through the provision of tips and facts within the interface such as 'did you know that water takes a lot of energy to pump and treat while energy takes a lot of water to produce? To save water, be mindful of your energy consumption!' on the homepage.

The impact of the user-interface on participants' consumption, knowledge and awareness is determined through the case study in the office setting, the trial of the interface by end users and water experts and the final questionnaires and focus group, described in the next chapter.

## 6.6. Appealing to Environmental Identity

According to the Cognitive Dissonance theory (Section 2.2.8), individuals strive for consistency within themselves [240], [241]. Internal inconsistency or dissonance due to conflicting values or attitudes lead them to either (a) rationalize their actions and sometimes live them with some psychological discomfort or (b) minimize this dissonant state [16], [240], [241]. However, according to the Self-Discrepancy theory, individuals want to reduce feelings of discomfort, dissatisfaction or disappointment and thus tend to act accordingly [16], [245], [246].

Similarly, the Symbolic Self-Completion theory (Section 2.2.8) considers that people feel complete once they have developed a complete self-definition [16], [247], [248]. To do so, they engage in self-symbolizing behaviours to show themselves and others that they possesses a certain identity [211], [247]. The more incomplete people feel, the more they try to achieve the desired identity though symbols [211], [242]. If people want to be perceived as eco-friendly but are not acting accordingly, it can be useful to inform them of the discrepancies in their behaviours [16], [240], [241]. This can make them feel incomplete and increase their performance of environmental actions [211], [247].

In the context of this study, participants' self-identity was assessed through the initial surveys and structured interview. More particularly, the structured interview included questions from a pro-environmental scale, developed based on New Environmental Paradigm & The Human Paradigm scale, and demonstrated that participants have positive attitudes and beliefs regarding water conservation and consider themselves as eco-friendly persons [149], [219]. In line with the Self-Perception Theory (Section 2.2.9), displaying comparisons between the users' past and current consumption encourages water-saving actions, especially when individuals consider themselves as eco-friendly [175]. By clicking on the 'comparisons tab' of the interface, users can decide to compare their current consumption to historical data (see Figure 6-14). That allows them to assess their progress and to estimate the results of current and past conservation efforts. More importantly, it intends to confront them to their daily water consumption. In case they see themselves as eco-friendly persons but do not act accordingly, this can motivate environmental actions by showing them discrepancies between their self-identity and their behaviours. The impact of the user interface on people's self-identity is tested though the trial phase, described in the following chapter.

## 6.7. Testing Social Influence

Participants' perceptions of social influence was assessed in the previous chapter. Contrary to experts, most respondents to the water consultation reported not feeling under social pressure to preserve the environment. These results confirm the Other Person Principle that states that people underestimate the impact of social influence [253], [254], [485]. The Theory of Reasoned Action and the Theory of Planned Behaviour (Section 2.2.1) however consider that individuals' behaviours are influenced by the community's expectations and perceptions of these behaviours [167], [171], [174]. They behave according to what they think is socially desired and want to give a positive image of themselves [167], [171], [174]–[176]. Subjective or social norms are either injunctive and encourage people to do what others think they should do or descriptive and leads people to do what others do [7], [173], [179], [485].

In line with this, the Social Learning Theory (Section 2.2.1) states that people acquire new behaviours by observing others' behaviours, especially the behaviours of people who are like them [179], [251], [252], [485]. Moreover, receiving a positive response from other people after performing the behaviour increases the performance of this behaviour [255], [256]. Informing individuals about others' behaviours can therefore encourage behaviours [11], [88], [134]. Regarding water consumption, if people believe that others do not limit their water consumption, they will be less inclined to reduce their own [330]. Conversely, displaying the water consumption of similar participating households can increase participants' water savings' efforts, especially if these households achieve important water savings [11], [88], [104], [134], [330], [512]. This can be done through comparisons between participants' water usage [63], [181]. On the comparison tab, individuals can compare their consumption with the average consumption of other participative households that are similar in size and occupancy [318].

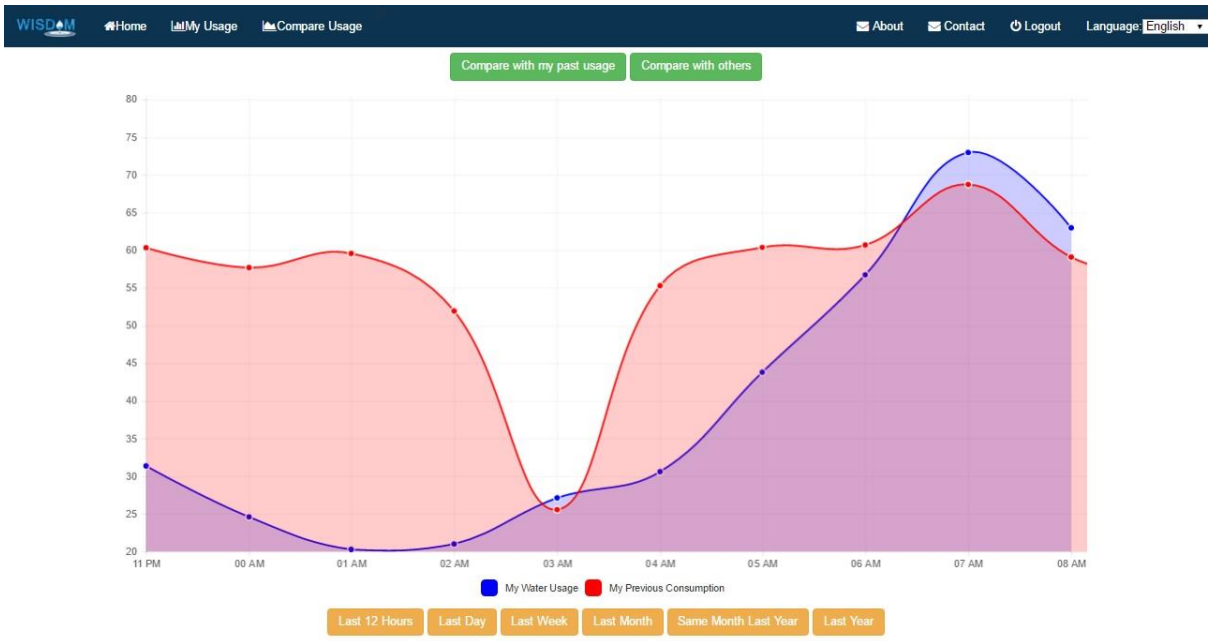



Figure 6-14. Comparison tab on the interface.

A social ranking is also displayed on the homepage to rank participants according to their water savings (see Figure 6-5). This ranking determines the households that are most involved in water conservation. In line with the Other Person Principle, the Social Learning Theory and the Social Cognitive Theory (Section 2.2.9), this shows participants how well they are doing at saving water compared to other households in order to influence their behaviours [250], [251], [252], [253], [254]. That way, competition is generated to motivate larger water savings [338], [353].

Figure 6-5. Social ranking feature.

Due to the impact of social networks on people's lives, consumers are also given the ability to share the results of their water reduction on websites such Facebook or Twitter (see Figure 6-6). This allows them to show that they are eco-friendly and could improve their reputation and the perception that others have of them [208]. Because social approval is sometimes a motivator of environmental action, it has also been shown that linking applications with social media encourage actions and participation from users [113], [206], [214], [385]. Displaying their consumption on social media and waiting for virtual approval from their friends indeed provide a form of emotional reward and make people feel that they are carrying out positive actions [339].

Figure 6-6. Access to social media.

Similarly, feedback about participants consumption, in the form of positive or negative 'emoticons', aim at encouraging water-savings either by approving or disapproving participants' behaviours in accordance with the Social Learning Theory (Section 2.2.1). The use of these features is assessed through the trial of the user-interface, the final questionnaires and focus group. Determining the frequency at which people check these features helps to understand the impact that social influence has on users.

## 6.8. Considering External Factors

The Theory of Planned Behaviour, the Value Action Gap, The ABC theory (Section 2.2.1, 2.2.2 and 2.2.3) all highlight the impact of situational influences and contextual forces on behaviours. These external elements vary from regulations to infrastructure, social expectations to monetary incentives [16], [113], [170]. They either encourage and prevent pro-environmental behaviours [187]. Strong contextual forces weaken the attitude-behaviour association [113], [188]. Personal behaviours that are difficult to perform and that require time and effort weaken of attitudinal factors on behaviours [113].

As indicated by the results from the Ask Cardiff survey (Appendix A), one of the contextual factors affecting conservation is the lack of communication between individuals and their water suppliers. The display has therefore been designed to reduce this barrier by facilitating the communication between participants and their water supplier through the 'contact' page (see Figure 6-15). Messages sent by the water supplier are displayed on this page and participants have the possibility to report a problem, make complaints or require information.

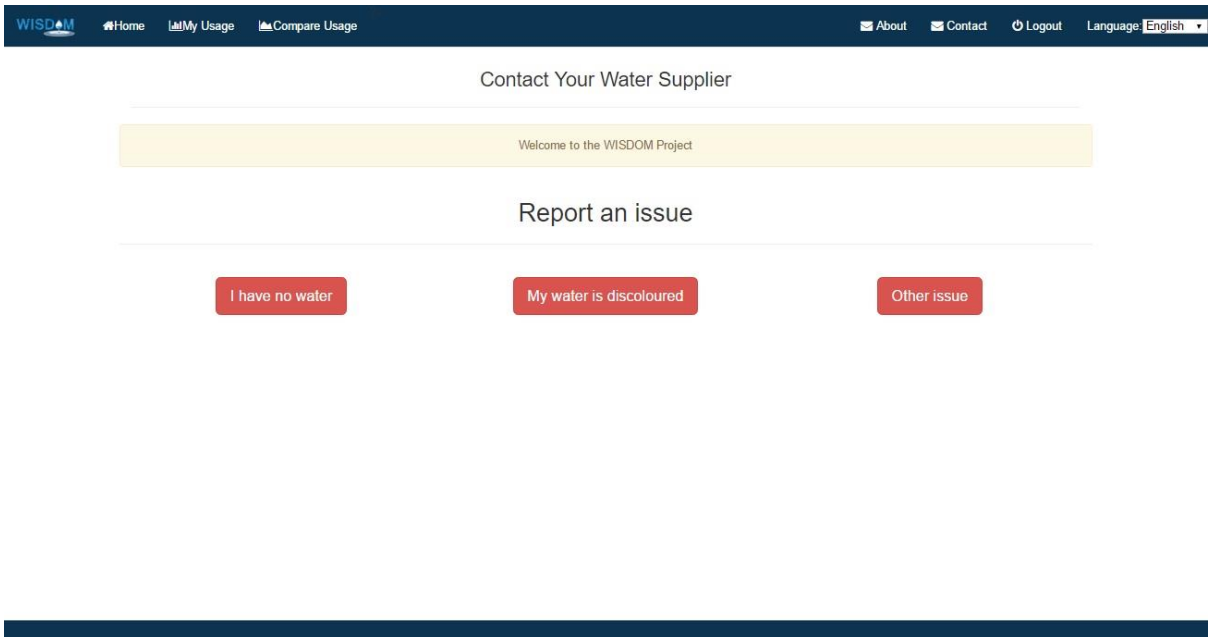



Figure 6-15. 'Contact' tab for interactions between users and their water supplier.

While more structural and global changes facilitating water conservation cannot be implemented in the context of this study, the trial phase described in the next chapter helps determining whether the implementation of the interface in households and in an office setting can encourage water conservation. Moreover, it provides further indications regarding the relationship between participants and their water company. This all gives insights as to the potential implementation of this kind of device on a larger scale and can inform future policies.

Based on the results from the initial surveys and on the literature (Chapters 2 and 3), the interface has been designed to encourage water savings and to help individuals develop more sustainable water habits and practices. To do so, different methods of encouraging behaviour change have been included within the interface to appeal to consumers with different interests and to promote larger water savings. The interface therefore includes:

Environmental features:

- quick and frequent feedback about water usage in the form of emoticons or messages,
- overview of the household's past and current global water usage,
- access to disaggregated data per appliances,
- facts about water consumption and water and environmental issues,
- tips and advice,
- a water saving target,

Financial feature:

- estimations of financial savings potentially achieved over time by saving water,

Social features:

- a social ranking,
- access to social media,
- social comparisons

Finally, the interface also makes it easier for users to communicate with their water supplier.

During the trial phase of this research project, the interface will be tried out by water experts, end users in households and end users in an office setting (Chapter 7). The aim is to determine the behavioural strategies and the type of information that can most efficiently reduce users' water consumption and promote water conservation in the UK. This will provide significant elements of answer to RQ3. This phase is also necessary to learn more about the use of the interface and the impact of such tool on individuals' water consumption, awareness of their water usage and knowledge of water and environmental issues. This will help answer RQ4.

# Chapter 7: Phase 3: Trial Phase

The design and implementation of the user-interface is a key aspect of this study. While this kind of interface has already been implemented in other countries, this study aims at assessing the potential of this technology in encouraging water savings and behaviour change in a context specific to the UK to fulfil OBJ4 [104], [175], [181], [513]. This specific context, i.e. the growing demand for water, the ageing infrastructure and the rainy climate, is indeed unique and the interface might not have the same impact in this country than in water-scare areas [30], [36], [46], [117]. Additionally, the interface includes different methods of encouraging behaviour change to determine the most efficient behavioural strategies to reduce water consumption. To the best of the author's knowledge, this has not been done by previous studies, in the context of the UK [104], [175]. Results from this trial phase are also particularly necessary to fulfil OBJ3 and OBJ4.

In line with the research process described in Chapter 4, this chapter describes the results from the second water experts' consultation conducted after having provided experts with an online access to interface (see Figure 7-1) (Section 7.1). It then presents the views and opinions of household members on the potential use of such device at home (Section 7.2). Finally, it details the implementation of the interface in an office setting and its impact through the description of the findings obtained from the post-trial questionnaire and focus group (Section 7.3). In this chapter, the findings are classified by themes. Thus, the sections include descriptive and inferential statistics and the analysis of the qualitative data where appropriate.

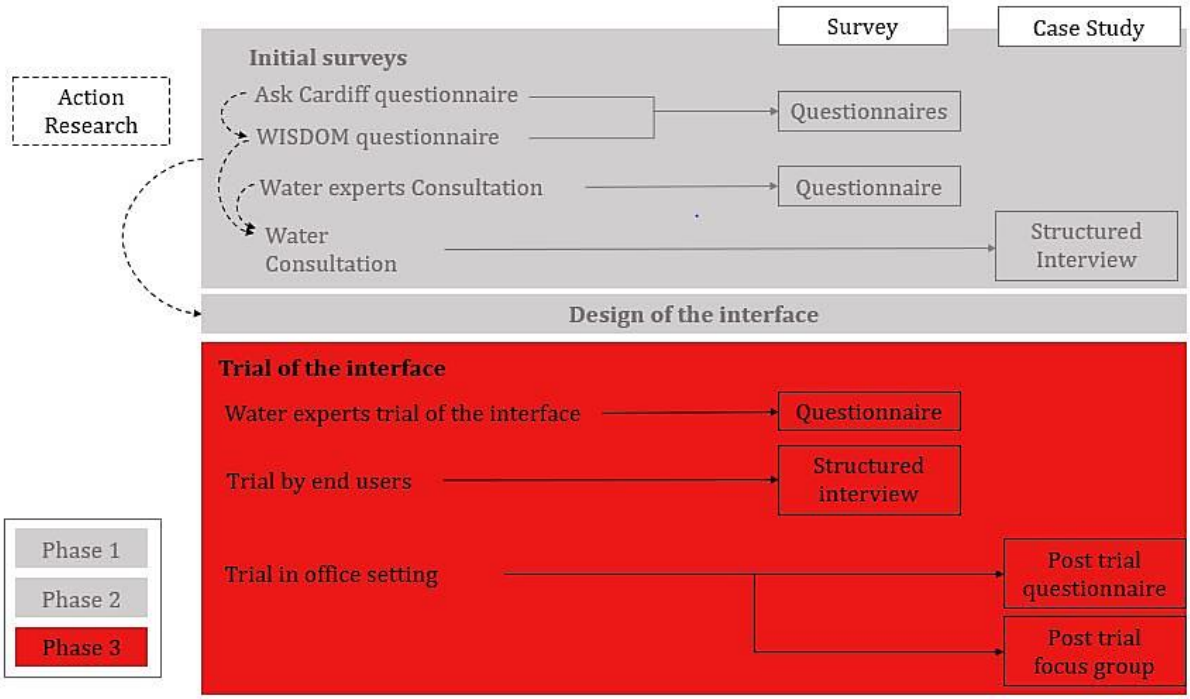



Figure 7-1. Focus of Chapter 7 (highlighted in red).

## 7.1. Second Water Experts Consultation: Trial of the User Interface

Following the first water experts' consultation (Chapter 5.3), experts were contacted again a few months later to validate the interface and its potential use by the general public (Appendix F). The aim was to answer of RQ3 and RQ4. At the beginning of the questionnaire, participants were provided with a link to the WISDOM online interface in which data representing a typical household had been entered. A username and password were also given to allow them to sign in into the interface. Examples of tips and facts provided to users on a daily basis were also described at the beginning of the survey.

First, some demographic data regarding their domain of expertise, their field of work and their place of residence was collected. Participants then had to assess the use of the interface. Open questions gave them the possibility to describe the positive and negative aspects of the interface. They could suggest improvements regarding its design and its content. Experts were then asked to evaluate the impact of the interface on users' water consumption and on their awareness of their water usage and knowledge of environmental issues. In addition, the optimal frequency of used was assessed by experts. Finally, as the use of new technologies can influence the interaction with the display, it seemed important to evaluate participants' use of technologies. This was done using the 'Technophilia scale' developed by [483] to measure affinity for technology. This scale includes various statements to assess on a 5-point Likert scale ranging from 'strongly agree' to 'strongly disagree'.

As mentioned in Chapter 4, to analyse the qualitative results obtained, a thematic analysis method was used, with the help of a researcher in psychology.

### 7.1.1. Demographics

Seven water experts took part in this second survey. These participants are all working in academia with one of them working in both academia and industry in the water domain. Three of them live in the UK while the others live in southern Europe.

The experts consider themselves as not being technophobic (57.1%), slightly technophobic (28.6%) or quite technophobic (14.3%). Overall, according to the Technophilia scale, the average Technophilia score among experts (39.1) suggest that they are rather familiar with the use of technology (see Table 7-1) [483].

Table 7-1. Percentage and grade point average of Technophilia items (post-trial questionnaire with experts).

| **Items – Do you agree or disagree that** | **SA** | **A** | **NAD** | **D** | **SD** | **GPA** |
|---|---|---|---|---|---|---|
| 1. Technology is my friend | 42.8 | 42.8 | 14.3 | 0 | 0 | 4.28 |
| 2. I enjoy learning new computer programs/apps and hearing about new technologies | 28.6 | 42.8 | 28.6 | 0 | 0 | 4 |
| 3. People expect me to know about technology and I don't want to let them down | 14.3 | 28.6 | 42.8 | 0 | 14.3 | 3.28 |
| 4. If I am given an assignment that requires that I learn to use a new program or how to use a machine, I usually succeed | 28.6 | 57.1 | 14.3 | 0 | 0 | 4.14 |
| 5. I relate well to technology and machines | 57.1 | 28.6 | 0 | 14.3 | 0 | 4.28 |
| 6. I am comfortable learning new technology | 57.1 | 28.6 | 14.3 | 0 | 0 | 4.43 |
| 7. I know how to deal with technological malfunctions or problems | 14.3 | 42.8 | 42.8 | 0 | 0 | 3.71 |
| 8. Solving a technological problem seems like a fun challenge | 28.6 | 0 | 28.6 | 28.6 | 14.3 | 3 |
| 9. I find most technology easy to learn | 14.3 | 71.4 | 14.3 | 0 | 0 | 4 |
| 10. I feel as up-to-date on technology as my peers | 14.3 | 71.4 | 14.3 | 0 | 0 | 4 |
| Cronbach's Alpha: .877 | | | | | | 3.91 |

SA: Strongly agree, A: Agree, NAD: Neither agree nor disagree, D: Disagree, SD: Strongly disagree

Responses to scale items were coded 1= Strongly disagree, 2= Disagree, 3= Neither agree nor disagree, 4= Agree and 5= Strongly agree [501], [502]. To assess the internal consistency of the

Technophilia scale, a test of reliability was conducted and a Cronbach's alpha value of 0.877 was obtained. This value shows a high level of internal consistency [503], [504].

### 7.1.2. Design and Content of the Interface

When asked about the positive aspects of the interface, experts report appreciating the layout and design of the interface, its ease of use and the type of information it provides; '*a lot of information nicely displayed, all in one page, easy graphics'* (see Table 7-2). For 85.7% of them, the interface is relatively easy to use. A large majority of experts (85.7%) consider that it provides the right amount of information about users' consumption. Moreover, all experts think the design is visually engaging.

Table 7-2. Report of the qualitative data (post-trial questionnaire with experts).

| Items | Main findings | Illustrative Quotes |
|---|---|---|
| **Positive aspects of the interface** | • Design (Graphics, colours, images)<br>• Ease of use<br>• Information provided | 'colour, simple language, easy to use, various information', 'the design of the interface, which is very friendly and easy to understand. The overview of water consumption as well as the financial savings can play a vital role in reducing consumption.' |
| **Negative aspects of the interface** | • Lay out<br>• Insufficient advice | 'a bit text heavy and more advice on ways to reduce consumption would be good', 'consumption figure is not clear' 'many different windows/tables'. |
| **Suggestions for improvements** | • Prioritise information<br>• Make the interface more visual | 'need to prioritise which information is most important',' more advice on 'how' to reduce shower time', 'more 'did you know' would be good', 'much more focus on virtual water'. |

Regarding the negative aspects of the interface, experts affirm that the lay out is not always clear; '*the menu for showing and hiding boxes is not very clear*'. Some of them also state that the tips provided are insufficient to directly encourage water savings '*One might wonder how do I reduce my water consumption?? The tips may be irrelevant to some users and they are not descriptive enough*'.

Improvements suggested by experts include making the interface more visual and prioritising the information depending the type of user i.e. new user or experienced user. More specifically, some experts suggest including more information about virtual water, more advice, videos and explanations. Most of them (57.1%) however agree to say that the 'financial savings' information

is more likely to capture users' interest, followed by 'facts, tips and advice' (28.6%) and comparisons and social ranking (14.3%). When asked to assess the impact of each feature on users' consumption, experts report that the 'comparisons and social ranking' and the 'facts, tips and advice' will have a low or moderate impact. Conversely, some of them affirm that the 'financial savings' and the 'overview of water consumption' features can have a high impact on users' consumption (see Table 7-3).

A binomial logistic regression was performed to ascertain the effects of participants' use of new technologies (Technophilia score) on the likelihood of finding the interface easy to use [488], [489]. Linearity of the continuous variables with respect to the logit of the dependent variable was assessed via the Box-Tidwell (1962) procedure. However, based on this assessment, the continuous independent variables (Technophilia score) was not linearly related to the logit of the dependent variable. A point-biserial correlation was then run as an alternative to determine the strength of the linear relationship between the participant's Technophilia scores and the likelihood of finding the interface easy to use [493]–[495]. However, the assumption of normal distribution was not respected and further analysis could not be performed.

Table 7-3. Experts' assessment of the impact of each feature on users' consumption.

| **Feature** | **No impact (1)** | **Low impact (2)** | **Moderate impact (3)** | **High impact (4)** | **M** |
|---|---|---|---|---|---|
| Overview of water consumption | -- | 28.6 | 42.9 | 28.6 | 3 |
| Comparisons and social ranking | -- | 57.1 | 42.9 | -- | 2.43 |
| Facts, tips and advice | -- | 57.1 | 42.9 | -- | 2.43 |
| Financial savings | -- | 42.9 | -- | 57.1 | 3.14 |
| | | | | | 2.75 |

### 7.1.3. Impact of the Interface

All the experts participating in the survey consider that the interface have the potential to increase users' awareness of their consumption, either slightly (28.6%), moderately (42.9%) or a lot (28.6%). Regarding the impact of the interface, most experts report that the interface can slightly or moderately increase users' awareness of water issues (71.5%) and of environmental issues (85.8%). Overall, the interface provides users enough guidance to reduce their

consumption and can encourage them to save water in both the long and short term (28.6%), in the long term (28.6%) or in the short term (42.9%).

Experts' opinions varied when it comes to the frequency at which users should use the interface. Some of them (42.9%) consider that, to have an impact on users' consumption, the device should be used daily while others (42.9%) consider that checking the device once weekly should be sufficient.

Results from this experts' consultation helped answering RQ3 and RQ4. First, experts believe that the interface is visually attractive and easy to use. They consider that using the interface can increase individuals' awareness of their own consumption and of water issues, especially if used on a weekly or monthly basis. Additionally, the financial savings feature is also the most likely to capture user's interest and to have an impact on their consumption. Suggestions for improvement include prioritising the information provided and including more tips and advice. The following section details the findings resulting from the trial of the interface in households.

## 7.2. Trial Among End Users in Households

Among the respondents to the water audit, ten accepted the invitation to try out the interface. A home consultation was arranged to show them the display and give them the opportunity to use it over a short period of time. Then, these respondents were asked a series of questions, based on a predefined questionnaire (Appendix G).

Participants first had to estimate their water consumption compared to the average consumption of similar houses. Their self-perceived knowledge of climate change and water issues was also reported. More specific questions about the interface were then asked. It was important to evaluate people's potential use of this kind of device on a daily basis and how difficult or easy it is for them to interact with it. The frequency at which they would be willing to check it and the features that they would check the most were also determined. In addition, respondents assessed the potential impact of the interface on their water usage, on their awareness of their water use and on their knowledge of water and environmental issues.

According to the Theory of Planned Behaviour, intentions to act pro-environmentally are influenced by people's perceived competency to perform a behaviour [177]. This implies that individuals need to perceive that they have the control and the required skills to perform a behaviour [7], [130], [172], [177], [183]–[185], [224], [225], [256]. Thus, to better understand their perceived behavioural control over their consumption, respondents were asked about the feasible opportunities they have to save water at home. Finally, they reviewed the positive and

negative aspects of the interface and had to possibility to suggest improvements regarding its design.

### 7.2.1. Interaction with the Display

Most of the respondents (60%) are not familiar with this kind of display and application. However, they consider that it is very easy (30%) or relatively easy (40%) for them to use the display. Thus, 90% agree or strongly agree that the display is overall easy to use. Most of them would be willing to check the device once a week (50%) or once a month (40%).

### 7.2.2. Design and Content of the Interface

The features that respondents would check the most if the interface was implemented in their household are the overview of their water consumption (70%), followed by the financial savings (20%) and the fact and tips (10%).

When asked about the negative aspects of the interface, some respondents consider that its design is too plain or basic (see Table 7-4). One interviewee also affirms that 'once novelty wears off logging into the interface, it'll probably be forgotten' and another mentions privacy concerns 'some people would find the data available intrusive'.

Table 7-4. Report of the qualitative data (post-trial questionnaire in households).

| Items | Main findings | Illustrative Quotes |
|---|---|---|
| **Positive aspects of the interface** | • Ease of use<br>• Visual information | 'Easy to use', 'simple, easy to ready and navigate', 'visual graphic, all in one place', 'simple interface', 'visualise your water demand'. |
| **Negative aspects of the interface** | • Basic design | 'a bit basic', 'a little plain'. |
| **Suggestions for improvements** | • More visual<br>• More colours<br>• Adaptable to mobile | 'A coloured background, possibly blue or green, to make boxes stand', 'more colourful', 'interactive and on one page so you don't have to scroll', 'mobile app', 'ensuring it is mobile view adaptive and graphics could be slicker'. |

A Mann-Whitney U test, a non-parametric test, was run to determine if there were differences in the likelihood of finding the display easy to use between group 1 'individuals who are familiar with the use of the display' and group 2 'individuals who are not familiar with the use of the display'[514]. Distributions of the frequency for the two groups were not similar, as assessed by

visual inspection. Frequency for group 1 (mean rank = 4.13) and group 2 (mean rank = 6.42) were not statistically significantly different, $U$ = 6.5, $z$ = -1.296, $p$ = 0.195 [515]. Eta squared ($\eta^2$ =.186) suggested a large effect size and group membership accounted for 18% of the total variance [472], [473]. To be more specific, the odds ratio of finding the display easy to use in group 1 versus group 2 is 0.2 (95% CI = 0.011 to 3.661) [516]. Surprisingly, individuals who are not familiar with the use of the display are five times more likely to find the display easy to use.

Similarly, a Mann-Whitney U test was run to determine if there were differences in the frequency at which individuals would be willing to check the interface between group 1 'individuals who are familiar with the use of the interface' and group 2 'individuals who are not familiar with the use of the interface' [514]. Distributions of the frequency for the two groups were not similar, as assessed by visual inspection. Frequency for group 1 (mean rank = 5.13) and group 2 (mean rank = 5.75) were not statistically significantly different, $U$ = 10.5, $z$ = -0.354, $p$ =0.724 [515]. Eta squared ($\eta^2$ =0.017) suggested a small effect size and group membership accounted for 1.7% of the total variance [472], [473]. The odds ratio of between the two groups, 1 (95% CI = 0.80 to 12.557), suggests that they have the same odds of checking the interface weekly or monthly.

A Mann-Whitney U test was also run to determine if there were differences in the frequency at which individuals would be willing to check the display between group 1 'individuals who find the display easy to use' and group 2 'individuals who find the display challenging to use' [514]. Distributions of the frequency for the two groups were not similar, as assessed by visual inspection. Frequency for group 1 (mean rank = 5) and group 2 (mean rank = 6.67) were not statistically significantly different, $U$ = 7, $z$ = -0.882, $p$ = 0.378, using an exact sampling distribution for $U$ [515]. Eta squared ($\eta^2$ =0.09) suggested a moderate effect size and group membership accounted for 9% of the total variance [473]. The odds of checking the display weekly are 2.667 (95% CI, .158 to 45.141) times higher if individuals find the display easy to use.

### 7.2.3. Impact of the Interface

A large majority of respondents (80%) consider that using the display would enable them to achieve water savings and would encourage them to save water (90%). 70% believe that it would also make them more aware of their water consumption. According to 90% of them, the display provides enough guidance to perform water-saving activities.

While 70% agree to say that they have enough opportunities to save water at home, half of the respondents (50%) report that it is challenging for them to save water at home, mainly because of other people: '*the wife', 'because of other people', 'two young children', 'kids, pets*'. Those who believe that they do not have enough opportunities for water conservation at home explain that

they are already efficient or already have efficient devices. However, using the display would make it very easy (40%), moderately easy (30%) or slightly easy (20%) for them to remember to perform water-saving tasks.

70% of respondents consider that they know very well or quite well about climate change (70%) and water scarcity and conservation (80%). Yet, most of them believe that using the interface would increase their knowledge of water issues (80%) and of environmental issues (50%).

A Mann-Whitney U test was run to determine if there were differences in the likelihood of considering that one does not have enough opportunities to save water at home between group 1 'individuals who find it easy to save water at home' and group 2 'individuals who find it challenging to same water at home'. Distributions of the frequency for the two groups were not similar, as assessed by visual inspection. Frequency for group 1 (mean rank = 4) and group 2 (mean rank = 7) were statistically significantly different, $U = 5$, $z = -1.96$, $p = .05$, using an exact sampling distribution for $U$ [515]. Eta squared ($\eta^2 = .43$) suggested a large effect size and group membership accounted for 43% of the total variance [472], [473]. The odds of considering that one does not have enough opportunities to save water are 2.5 (95% CI = 0.137 to 1.170) times higher if individuals find it challenging to save water at home.

A Mann-Whitney U test was run to determine if there were differences in believing that the display can increase one's knowledge of water issues between group 1 'individuals who know very well about water' and group 2 'individuals who do know quite or fairly well about water issues' [517]. Distributions of the frequency for the two groups were not similar, as assessed by visual inspection. Frequencies for group 1 (mean rank = 5.9) and group 2 (mean rank = 5.1) were not statistically significantly different, $U = 10.5$, $z = -.454$, $p = .650$, using an exact sampling distribution for $U$ [515]. Eta squared ($\eta^2 = .02$) suggested a small effect size and group membership accounted for 2% of the total variance [472], [473]. The odds ratio of between the two groups, 1 (95% CI, .045 to 22.175), suggests that they have the same odds of believing that the display can increase one's knowledge of water issues.

To further the analysis of the impact of the interface, an office setting trial was organised in addition to the households' experimentation. The following section describes the findings from this two-week long trial and provides insights as to the impact of the interface on users' awareness of their consumption and knowledge of environmental issues when installed in a building. Results of these two experiments will be summarized together and detailed at the end of this chapter.

## 7.3. Trial in an Office Setting

To validate and learn about the impact and use of the interface, a trial was organised in an office setting. The water consumption of the building had been monitored a few weeks earlier. While the meter was removed prior to starting this trial, the interface displayed randomised data that had been previously collected.

This office is situated in a converted house. It is occupied by 40 people and is equipped with three open space offices, a meeting room, two toilets, a bathroom including a shower, and a kitchen. The water-using appliances installed in this building, similar to the ones found in houses, offer opportunities for water saving. While water consumption at home and at work differ, implementing the interface in such setting can therefore potentially encourage a number of feasible water-saving practices. Additionally, by informing individuals about the building's water consumption and about water issues, the aim is to raise individuals' awareness to promote water conservation in offices and households.

### 7.3.1. Implementation of the Interface

For the purpose of this trial, a user interface has been installed in the communal area of the building. As it is suggested in the literature that displays should be installed in highly trafficked areas of a building, the display was implemented next to a sitting area often used by occupants [61], [90]. The interface remained in this location for the duration of the study. The study took place between the 18th of July until the 31st of July 2017. As it was summer months, some occupants were away on holiday which reduced the number of participants in the study.

The individuals remaining in the building were informed of this study by email (Appendix H). To encourage the adoption of an innovation, it is important to communicate the environmental, social and personal benefits of the innovation [176], [266]. Thus, the email gave indications regarding the duration of the study, the location of the display in the building and the features included in the display. It also specified that some of features were not available as they had been designed for an average household and not for a building of this size. These included the 'water-saving goal', 'the 'social ranking' and the 'comparisons with others' features. As there was only one building considered for this trial, its water consumption could not be compared to other buildings'. Due to the unique characteristics of this building, it would have been challenging to find 'similar others'. Another email was sent to the participants mid-way though the trial to remind them of the interface. However, to ensure that the participants' attitudes were not

influenced by the researcher, contact with the participants during the trial phase were limited to these emails and the researcher was not present in the building at that time.

### 7.3.2. Questionnaire

At the end of the two weeks, an online questionnaire was sent to the occupants of the building (Appendix I). To get a demographic overview of the participants, questions related to their status, age and country of origin were asked. Then, respondents were asked whether they had looked at the interface over the course of the trial. Those who replied negatively were led to a question asking about the reasons for their lack of interaction with the interface. Those that answered positively had access to the rest of the questionnaire. This included questions regarding the information provided by the interface, the number of times they checked it during the trial, their impressions regarding its use and design and suggestions to improve it.

The impact of the interface was then assessed through questions regarding the evolution of participants' awareness of the building's water consumption and knowledge of environmental and water issues. The features that were used the most were assessed based on users' report of their use of the interface. Individuals were also asked whether they remember some of the tips and advice provided. To verify whether they did remember, those who responded positively had to write down one of the tips provided during the two weeks. Additionally, in order to understand the potential use of such an interface in a domestic environment, respondents' willingness to use this kind of device at home and to invest in it was evaluated. Finally, it was necessary to assess participants' general use of technologies as it could potentially influence their use of the interface. Therefore, in accordance with the Technophilia scale, participants had to assess a number of affirmations on a 5-point Likert scale ranging from 'strongly agree' to strongly disagree'[483]. They also had to report whether or not they considered themselves as being 'technophobic'.

To gain more in-depth knowledge about the use and impact of the interface, respondents to this questionnaire were asked to provide their email address if they wanted to take part in a focus group to share their experience of the interface. The focus group was conducted a week after the end of the trial.

#### 7.3.2.1. Demographics

Eleven individuals filled in the post-trial questionnaire. These participants mainly come from Europe (72.7%). The rest of them is originally from China (9.1%), Sri Lanka (9.1%) and Saudi Arabia (9.1%). 54.5% are aged between 20 and 25 years old, 18.2% between 26 and 35 years old, 18.2% between 36 and 45 and one participant is over 46. Overall, the average

Technophilia score among participants is high (42.3) and suggest that participants are very familiar with the use of technology [483].

Table 7-5. Percentage and grade point average of Technophilia items (post-trial questionnaire in office setting).

| **Items – Do you agree or disagree that** | **SA** | **A** | **NAD** | **D** | **SD** | **GPA** |
|---|---|---|---|---|---|---|
| 1. Technology is my friend | 81.8 | 18.2 | 0 | 0 | 0 | 4.81 |
| 2. I enjoy learning new computer programs/apps and hearing about new technologies | 72.7 | 27.3 | 0 | 0 | 0 | 4.73 |
| 3. People expect me to know about technology and I don't want to let them down | 18.2 | 36.4 | 36.4 | 9.1 | 0 | 3.63 |
| 4. If I am given an assignment that requires that I learn to use a new program or how to use a machine, I usually succeed | 54.5 | 36.4 | 9.1 | 0 | 0 | 4.45 |
| 5. I relate well to technology and machines | 54.5 | 36.4 | 9.1 | 0 | 0 | 4.45 |
| 6. I am comfortable learning new technology | 63.6 | 36.4 | 0 | 0 | 0 | 4.64 |
| 7. I know how to deal with technological malfunctions or problems | 27.3 | 27.3 | 45.5 | 0 | 0 | 3.82 |
| 8. Solving a technological problem seems like a fun challenge | 18.2 | 36.4 | 18.2 | 27.3 | 0 | 3.45 |
| 9. I find most technology easy to learn | 36.4 | 54.5 | 9.1 | 0 | 0 | 4.27 |
| 10. I feel as up-to-date on technology as my peers | 27.3 | 45.5 | 27.3 | 0 | 0 | 4 |
| Cronbach's Alpha: .873 | | | | | | 4.23 |

SA: Strongly agree, A: Agree, NAD: Neither agree nor disagree, D: Disagree, SD: Strongly disagree

Responses to scale items were coded 1= Strongly disagree, 2= Disagree, 3= Neither agree nor disagree, 4= Agree and 5= Strongly agree [501], [502]. To assess the internal consistency of the Technophilia scale, a test of reliability was conducted and a Cronbach's alpha value of 0.873 was obtained. This value shows a high level of internal consistency [503], [504].

#### 7.3.2.2. Interaction with the display

Ten participants interacted with the interface over the two-week period. Only one participant reported not checking the display over this period. When asked about the reason preventing him/her from doing so, the participant stated that he/she forgot. This individual did not have to answer the remaining questions of the questionnaire. After analysis of the Technophilia score, it appears that this person had the lowest score of the group. While conclusions cannot be drawn from this fact, it seemed important to mention it. The other

respondents checked the display several times a week, (50%), once a week (27.3%) and once over the two-week period (18.2%).

#### 7.3.2.3. Design and Content of the interface

The interface is considered very easy (50%) or relatively easy to use (50%) by the respondents. 90% also believe that it is visually engaging. A participant was however confused by the lack of labels on the graph and by the time scale described in the 'past consumption' tab; '*When comparing with the past consumption, we do not know when this past consumption occurred. Yesterday actually means the last 24 hours and last week means the last seven days. It can be confusing'*. Participants' impressions are described in more details in the table below (see Table 7-6).

Table 7-6. Report of the qualitative data (post-trial questionnaire in office setting)

| Items | Main findings | Illustrative Quotes |
|---|---|---|
| **Positive aspects of the interface** | • Engaging<br>• Ease of use<br>• Tips provided<br>• Information about consumption | 'It is engaging and makes it simple to check your real-time water consumption', 'it's easy to use with the touch screen', 'provides an engagement and monitoring tool', 'tips and information are interesting', 'it provides tips that are useful to help saving water, 'good insight on water consumption'. |
| **Negative aspects of the interface** | • Lack of units displayed<br>• Provides no disaggregated data | 'I would like to be able to differentiate between different types of water usage or room wise', 'how much water each activity is using (showers, making a tea…)?', 'I couldn't find the units on some graphs'. |
| **Suggestions for improvements** | • Include disaggregation data<br>• Display a summative period of data | 'Having a monthly or weekly average screen with a trend line', 'a clear dashboard to see if you are doing well during the current day', 'precision on where the water was consumed: is it the toilets, the tap, etc.'. |

Regarding the information provided by the display, 54.5% of the respondents consider that the display provides the right amount of information about the building's water consumption

whereas 36.4% believe that it provides too little information. The overview of the building's water consumption is the most frequently checked feature for 90% of the participants, followed by the comparisons and social ranking features (10%). Half of the respondents remembered some of the tips and advice provided by the display. This was verified by their responses when they were asked to write down the tips they remembered. These tips include: saving water for the plants, not brushing teeth under the shower, using a glass of water when brushing teeth, using a bowl when washing the dishes, collecting the water when it is heating up and using it for other purposes.

A point-biserial correlation was run to determine the strength of the relationship between the participant's Technophilia scores and the likelihood of finding the interface easy to use [493]–[495]. Group 1 refers to individuals who consider the interface as a very easy and Group 2 refers to those who consider it as relatively easy to use. Data are mean ± standard deviation, unless otherwise stated. Preliminary analysis showed that there were (a) no outliers in the data, as assessed by inspection of a boxplot for values greater than 1.5 box-lengths from the edge of the box, (b) the Technophilia scores were normally distributed for both Group 1 and Group 2, as assessed by visual inspection of Normal Q-Q Plots and (c) there was homogeneity of variances for the Technophilia scores of Group 1 and Group 2, as assessed by Levene's test for equality of variances ($p$ = .216). There was a small but not statistically significant correlation between the two variables p=.265. Cohens'$d$ (-.2) suggested a small effect size [472].

A Cochran-Armitage test of trend was then used to determine whether there was a linear trend between age and finding the interface easy to use (see Table 7-7)[490], [491]. The null hypothesis tested was '$H_0$: There is no linear trend in binomial proportions across age categories'. The age categories included were 20-25 (n=6), 26-35 (n=2), 36-45 (n=2), over 46 (n=1), and the proportions of respondents who reported finding the display very easy to use was .5, .1, 0, 0 respectively. The Cochran-Armitage test of trend did not show any statistically significant linear trend between the two variables. $p$ = .136. Therefore, we accept the null hypothesis stating that 'there is no linear trend in binomial proportions across age categories'. Yet, the odds ratio of finding the interface relatively easy to use is 0.5 in age 20 to 25 versus age 36 to over (95% CI = 0.225 to 1.113) and 0.5 in age 20 to 25 versus age 26 to 35 is 0.5 (95% CI = 0.225 to 1.113). This suggests that younger individuals are twice less likely to find the interface easy to use.

Table 7-7. Summary of the statistical analysis for the 'demographics' variables.

| Variables | Test | Sig. | Pearson Correlation |
|---|---|---|---|
| Technophilia scores/Finding the interface easy to use | Point-biserial correlation | .216 | .390 |
| Age/ Finding the interface easy to use | Cochran-Armitage test of trend | .136 | N/A |

#### 7.3.2.4. Impact of the interface

All participants consider that the interface increased their awareness of the building's water consumption, either slightly (18.2%), moderately (54.5%) or a lot (18.2%). Regarding their awareness of water issues, one respondent report that his/her awareness did not increase with the use of the interface. The rest consider that it did increase slightly (54.5%) or moderately (27.3%). Likewise, using the interface slightly (54.5%) or moderately (18.2%) increased their awareness of environmental issues. Additionally, the participants overall report that the interface gave them enough guidance to reduce their water consumption at home and at the office (81.8%). Most of them consider that using the display could encourage them to save water in both the long and short term (72.7%). 90.9% would use this kind of device at home and 45.5% would invest in it for their personal use.

### 7.3.3. Focus group

To learn more about the use of the interface during the trial in the office setting, four persons took part in a focus group conducted after the end of the trial [452], [453]. As mentioned in Chapter 4, despite being small, this sample size fits into the recommended sample size for a focus group in thematic analysis [452], [453]. These four individuals were asked about their interaction with the interface during its implementation in the building. This focus group was organised on Friday the 11th of August between 2pm and 3pm. The discussion lasted for 45 minutes and was recorded and transcribed. Notes were also taken to ensure that non-verbal interactions were reported.

Questions regarding the use of the display were first asked. These included questions regarding the design of the display and its location in the building. Respondents were also asked to discuss the potential use of this kind of tool at home. This led to a more general question about water consumption, including water pricing and the role of water companies in the UK.

#### 7.3.3.1. Demographics

The four individuals who agreed to share their opinions on the interface during the focus group are all aged between 22 to 35 years old. Three of them are males and one is female.

When asked whether they consider themselves as eco-friendly persons, participants state that they are average or above average; *'reasonably eco-friendly', 'I am eco-friendly, I'm trying at least', 'I think I am eco-friendly. I am the kind of friend that keeps telling everyone to save water and save the planet'.* Participants, especially the two interviewees who described themselves as eco-friendly, perform a wide variety of eco-friendly activities in their daily life, ranging from eating less meat to recycling and using sustainable means of transport; *'I do have a car but I try not to use it too much unless I really need it', 'I take the train', 'I cycle to work or walk'.*

#### 7.3.3.2. Interaction with the display

Participants agree on the fact that the interface was not well located within the building. One interviewee state; '*at first, I didn't notice it*'. In the participants' opinion, it should have been placed in a more frequented place, such as the breakroom or at the top of the stairs.

#### 7.3.3.3. Design and Content of the Interface

Participants affirm that the display is easy to use and user-friendly. Regarding its content, they particularly appreciate the tips provided and the comparisons feature. All of them would be willing to use such a device at home. They however recommend some suggestions such as being able to compare the building's consumption to others' and having access to disaggregated data (see Table 7-8). Participants believe that the inclusion of a game could be a good way to encourage people who do not have an interest in water conservation to achieve water savings; '*I think it's the best way to have an impact on people who don't really care for the environment', 'I think it would be really nice for children'*.

In addition, participants believe that their use of the display will probably fade over time. Alerts would therefore be useful to remind them of excessive water consumption. However, these alerts should not be too regular; *'when you go 10% above your usual consumption, maybe you can have an alert, not on a regular basis', 'if you have one alert a day at the end you don't pay attention'*. The use of ancillary features is also suggested as it could increase the interaction with the display. Two interviewees referred to examples from the use of their energy displays; '*if I compare with the power meter, I looked at it several times a day the first week and less after that but it's really well placed in the kitchen so when I turn on the stove I can see it going red. It's not intentional, I don't look at it, but I see it', 'most of the time I realise that I check the smart electricity meter because I want to check the time when I cook pasta'.*

Participants also discussed the use of the display by older generations. They believe that such device is appropriate for individuals from their own generation; '*for our generation I think it's pretty good cause it's interactive and really easy to use'*. However, it might not be suitable for older persons; '*[talking about his grand-parents] they see a touchscreen, they panic, even though you touch it like any button on your phone'*. Participants also acknowledge that some persons might have privacy concerns. As an example, they mentioned that their peers, i.e. parents and grand-parents, are very concerned about their privacy and might therefore be reluctant to use the interface; '*my mother is always afraid of somebody watching her or trying to know stuff about her, I think it's not the right tool*', '*my parents as well are very concerned about privacy. They're scared that smart meters are used to spy on them'*, '*In the case of my parents they still wouldn't like it [even if they were informed about the purpose of collecting their data] they think it's not a problem right now but if the regime changes it could be a real problem later'.*

Table 7-8. Report of the qualitative data (focus group).

| **Items** | **Main findings** | **Illustrative Quotes** |
|---|---|---|
| **Positive aspects of the interface** | • Ease of use<br>• User-friendly<br>• Tips provided<br>• Comparisons features | ''it was easily understandable', 'there wasn't any problem to understand what the buttons are and what they do, 'the design was ergonomic, 'I like the fact you can compare with your previous consumption', ' I liked the tips part because if you see that your consumption is high, it's nice to have some tips to help you reduce it'. |
| **Negative aspects of the interface** | • Time limits | 'I would use it maybe less frequently over time', 'or every month when you receive your bills', 'at first I would look at it every day and after a while just not really use it anymore apart from the alerts'. |
| **Suggestions for improvements** | • Comparisons with neighbours<br>• Alerts<br>• Goals and objectives<br>• Disaggregated data<br>• Add ancillary features<br>• Water game | 'I think it would be fun to have other people to compare your consumption to because you don't want to be above the average', 'the display could tell you at a moment of the day "careful you go above"', 'you could set consumption goals and objectives, that would be good too', 'a kind of life bar that goes through the day so you know where you're at in your objective of the day', 'I would have liked to have the difference at least between the kitchen and in the bathroom', 'it's easier to spot a leak this way', 'if children really get into the game they might tell their parents not to spend that much water because they keep an eye on the fish'. |

#### 7.3.3.4. Impact of the Interface on water usage

According to the participants, this kind of display is not adapted to an office setting. Participants feel that they do not have enough opportunities to reduce their consumption in such an environment; '*there is not much you can do to lower your consumption cause pretty much everything you do is drinking coffee or going to the toilet*'. The fact that they do not pay the bills also influences their consumption; *'I think that because we don't pay the bills here, we're also less motivated to save water'*. Participants however acknowledge that this kind of display could be useful for the building managers who can then influence the employees; '*If the price depends on the time and if the building manager says that at a certain time there is a peak load, he can plan it and start saving water in low peak hours*'.

Overall, participants consider that it is difficult for them to save water; *'I think water is one of the hardest thing to save cause you don't really know what you could do to further reduce your cnsumption', 'it's quite easy to save electricity but water is a bit more tricky', 'the thing about spending less time in the shower is that it decreases your level of comfort so much'.* The UK specific context was also brought up by one of the interviewee; '*Here it is hard to feel concerned about the amount of water you spend because you feel that there is water everywhere'.* They however acknowledged that receiving tips, such as the ones provided by the display, can help them reduce their consumption; '*because you won't look for tips by yourself', 'because the display suggested to use a bowl, I just keep on trying to do that'.*

Participants agree that providing information about virtual water footprint can raise people's awareness; *'I think people are not aware of their water footprint', 'even me, a bit aware, I don't really know a lot, I just know about red meat and cotton, but I think most people are not aware*'. They also affirm that providing such information can ease the performance of water-saving activities and can encourage a gradual change in habits; *'I think it's much easier to try and advice people to use clothes and food that are less water consuming than to tell them to spend 5 minutes less in the shower every day. I think it is easier to change your habits little by little', 'there are simpler way to reduce your water footprint than there are to reduce you actual consumption', 'Especially if you compare it; one kilogram of meat uses as much water as you in one year, that would have such a huge impact because you would be like "I've been trying to reduce my water for a month but if I had just eaten less meat, it would have had the same impact". I think that would be pretty useful'.*

#### 7.3.3.5. Financial matters

One interviewee stated that he would have preferred to see the building's water consumption displayed in pounds sterling (£) rather than litres. This led to a discussion about the impact of displaying the cost of water. For other interviewees, the cost of water is low which is

'*not really motivating'*. They therefore suggest that users should be able to choose the units they want to see displayed on the interface.

Overall, participants consider that people who use more water should not pay more for their usage. The main reason given by participants is that this could affect poorer individuals; '*You can be poor and consume a lot because you don't have the necessary appliances*'. This is also relevant for adaptive pricing and peak tariffs; '*the people who have the choice to change their consumption are usually the richest people', 'if you have a high responsibility profession, you can say 'okay I will go to work at 10 and be late' but if you are a worker and have to work really early, you don't get to choose'*.

While they agree that they would use the interface at home, participants' responses are mixed when it comes to investing in a potential in-home display. One interviewee affirm that she would be willing to pay for it but only to a certain extend; '*I wouldn't pay over £20 for it*'. Two other participants would expect their water supplier to pay for it adding that; '*they should be covered by the bills*'. One interviewee consider that the price of the interface might not be worth the financial savings that water conservation can achieve; *'because if you save £10 on a year for water and you buy a £20 device to do so, you just lose £10'.*

#### 7.3.3.6. The Role of Water Companies

Over the course of the discussion, water companies were often compared to energy suppliers. Participants agree to say that water companies need to be more pro-active, to provide them with tips and advice; '*if I compare my electricity provider and Welsh Water, Welsh Water is very quiet, I never hear from them', 'British Gas informed me about energy savings, they provided me with the mobile application, with smart lightbulbs for free. When the technician came he had to go through a list of energy saving tips. Even though we already knew, he had to do it*'. They affirm that they trust the information provided by their supplier: '*It's nice to see that the company itself has a policy of awareness raising because you tend to listen more to your provider than to other people*', '*I feel they are telling me to save energy even though that means less money for them. That must mean that they have environmental awareness, that they care about the planet and not just about their profit', ' they don't make profit out of it so it means that [environmental issues] do exist I guess'.*

The trial phase of this research, conducted in an office setting and on end-users and water experts, aimed at learning more about the user interface, its potential use and impact on users' water consumption and on their knowledge and awareness of water conservation. In addition, this trial also helped fulfilling the following research objectives:

- OBJ3: Identify the methods of encouraging behaviour change and water savings that are most effective across consumers with differing views.
- OBJ4: Determine whether the use of near real-time user-orientated water feedback system promotes behaviour change and water conservation.

To increase the efficiency of the interface, its design has been tailored according to the literature (Chapters 2, 3), the results of the initial surveys and of the first water experts' consultation (Chapter 4). The interface was first used by end users that took part in the water consultation and by water experts. It was then implemented in an office setting over a period of two weeks. Participants to this trial phase gave their opinions on the use of the interface through an online questionnaire and during a focus group. The main findings resulting from this stage of the project include:

- The interface is easy to use and visually engaging.
- The interface can encourage users to save water.
- The interface provides good tips and enough guidance to save water.
- The interface increases users' awareness of their (of the building's) consumption.
- The interface increases users' knowledge of water and environmental issues.
- Saving water at home is challenging.
- Overall, participants are ready to check the device once a week or more.
- The overview of water consumption is the most commonly checked feature of the interface.
- Disaggregated data should be included within the interface.
- Participants would be willing to use such a device at home but are less likely to invest in it.
- The use of the interface might fade over time.
- Some individuals might be concerned about their privacy when using the display.

To address OBJ4, the interface received positive feedback and is considered as an adequate tool to encourage domestic water savings. Its use fulfils the requirements from the TAM which implies that it is likely to be well-received and used by individuals. Most of them indeed consider that it is easy to use and visually attractive. Regarding OBJ3, results from the trial phase gave insights as to the methods of encouraging behaviour change that have most impact on users. The fact that participants are interested in the overview of their water consumption and in the financial savings tabs is in line with the rest of the surveys and reflects both their interest in water conservation and their financial concerns. While improvements regarding its location and its content have been suggested, these initial results demonstrate that the interface can encourage water savings and promote water conservation. Indeed, respondents considered that the interface is useful to increase their awareness of water consumption and their knowledge of water issues and eases the performance of water-savings activities. Yet, saving water is challenging for many respondents, which can limit the impact of the interface on a practical level.

Additionally, privacy concerns could hinder its acceptance by the public and it is crucial to inform users about the protection of their data when using the interface. Finally, a few users also feared that the interaction with the interface could fade over time.

The following chapter provides a bigger picture of the results presented in Chapters 4, 5 and 7. The main findings are analysed in the light of the literature described in Chapters 2 and 3. This leads the author to draw conclusions regarding the knowledge acquired in the context of this research project. In addition, based on this discussion, Chapter 9 offers suggestions for future work and recommendations as to the most efficient ways to implement and validate the interface in households.

# Chapter 8: Discussion

This chapter discusses the results presented in Chapters 4, 5 and 7. The aim is to draw conclusions regarding the use of a user-interface to encourage water savings and promote water conservation in the UK and to provide answers to the four objectives. This chapter is therefore divided based on these objectives.

- OBJ1: Identify water users' current level of awareness of their water consumption and attitudes towards water usage.
- OBJ2: Assess the current level of preparedness for change among water users.
- OBJ3: Identify the methods of encouraging behaviour change and water savings that are most effective across consumers with differing views.
- OBJ4: Determine whether the use of near real-time user-orientated water feedback system promotes behaviour change and water conservation.

For each objective, results from the initial surveys and from the trial phase are described considering the literature. Limitations to behaviour change that emerged from the results and results that differ from the literature are also described to better fulfil the research objectives. Explaining some of these limitations sets this study into a more global and national context by discussing the price of water in the UK or the role of water companies in this country. This shows that the general context of the UK is not particularly favourable to the promotion of domestic water conservation. Based on the results and on the literature, recommendations are therefore suggested to efficiently promote water conservation in this context. More detailed suggestions for future research are described in the next chapter.

Finally, the last section focuses on the methodological limitation of the study. It describes the self-selection sampling method used to recruit participants and explains its impact on the results obtained.

## 8.1. OBJ1: Identify Water Users' Current Level of Awareness of Their Water Consumption and Attitudes Towards Water Usage

The Theory of Reasoned Action and the Theory of Planned Behaviour consider that behaviours are directly influenced by intentions that are themselves influenced by attitudes, subjective norms and perceived behavioural control [7], [113], [184], [185]. In order to change behaviours, it is therefore crucial to assess these three elements. Attitudes towards an environmental behaviour refer to the positive or negative evaluation of the outcome of the behaviour based on factual environmental knowledge [170], [171]. In the context of this study, attitudes towards water conservation have been assessed through the initial surveys. It was also

necessary to estimate individuals' level of awareness of their water consumption prior to implementing the interface in order to correctly evaluate the impact of this tool on awareness at the end of the trial.

### 8.1.1. Positive Attitudes Towards Water Conservation

This section discusses the socio-demographic characteristics of the participants, their attitudes and habits regarding water usage. It brings together these elements in light of the literature and argues that participants to the surveys are environmentally-friendly individuals that are inclined to reduce their water consumption and, thus, are likely to make a positive use of the interface.

Chapter 2 gave guidance regarding the socio-demographic factors to evaluate and the first surveys were designed to assess these factors on the population studied. This is a necessary step to better understand participants' attitudes and habits regarding water consumption. The literature demonstrated that some socio-demographic factors encourage pro-environmental attitudes. First, women are more emotionally engaged and concerned about environmental issues and more likely to engage in water conservation behaviours [124], [130], [133], [138], [139], [152]. Likewise, older generations are more inclined to adopt sustainable behaviours, even though they are less likely to develop environmental beliefs [150]. In the UK, it also seems that older individuals are more likely to perform environmental behaviours [124], [152]–[154]. Some authors also state that individuals with a higher level of education are more likely to engage in pro-environmental behaviours [64], [129]. This is true in the UK where individuals with higher levels of education tend to adopt more pro-environmental behaviours [121], [152]. Households with higher employment status also tend to spend less on water per week [31]. House owners invest more in water-saving devices than people renting houses and individuals living in semi-detached use less water on average [140], [153]. Finally, regarding the household composition, the literature affirms that smaller households use less water, especially when they do not include children [2], [125], [148].

In light of this literature, the socio-demographic characteristics of the participants to the surveys suggest that they are inclined to demonstrate pro-environmental attitudes. First, following expected trends in the UK, female participants to the surveys are slightly more inclined to save water for environmental reasons [127]. Regarding age, a large proportion of respondents to both the Ask Cardiff and the WISDOM questionnaires (Appendixes A and B) are over 50 (55.56% WISDOM) or 55 years old (42.8% Ask Cardiff). In line with this, the results suggest that individuals aged 35 and over are more likely to consider water as an important issue than individuals between 16 and 34. Overall, it also appears that participants are more likely to

consider water conservation as an important issue as age increases. [460]. Similarly, the high level of education and employment status of the participants suggest that they are inclined to adopt pro-environmental behaviours. The odds ratio indeed demonstrated that individuals with diploma or advanced diploma are on average two times more likely to consider water conservation as an important issue than other individuals [459]. Most of the respondents to the WISDOM survey had a postgraduate qualification or university degree (26.3%). Likewise, the results showed that employed individuals are more likely to invest in water-saving devices than self-employed individuals, retired individuals and business owners. The willingness to buy and install water saving devices was indeed better predicted by the employment status of the participants [497], [498]. Half of the participants of the WISDOM questionnaire was employed or self-employed (62.6%).

In line with the literature, the results also demonstrated that the odds of investing in water-saving devices are slightly higher if individuals owe their properties than if they rent [460]. However, while 64% of respondents are house owners, a little less than half of the respondents reported having a water meter installed (48.8%) and only 15.1% reported having water-saving devices at home. Semi-detached houses (34.85%) and terraced houses (33.84%) were the most common types of home among the respondents which suggests that these individuals tend to use less water. While most of the respondents owned a lawn or a garden (79.3%) and an external tap (68.2%), majority of them (64%) indeed never use water for garden purposes during summer and only 20.2% water their garden during the year. In addition, 50.5% of the respondents collect rainwater, and out of those, a large majority does so to water their garden. In Chapter 2, it was demonstrated that the weather influences the way people use water. The results obtained can therefore be explained by the fact that the weather in Wales is often cloudy and wet which limits the need for garden watering and offers more opportunities for rainwater harvesting [519]. Finally, in line with the literature, results from the water consultation (see Appendix E) showed that a high households' occupancy increases the number of showers taken within the households [505]. Households with children did report a higher frequency of baths than households without children. Yet, most participants to the consultation and to the WISDOM survey reported living on their own or just with another person and only minority of respondents to the consultation reported having children living in the house.

According to the literature described in Chapter 2, respondents' socio-demographic characteristics are likely to illustrate pro-environmental attitudes. This was indeed verified by the positive attitudes towards water conservation reported through the surveys. Most of the respondents consider water conservation as an important issue and want to save water. Water conservation is "important" or "very important" to many of them in their daily lives. This belief

therefore increases the number of water-saving habits performed within households. Overall, with an average score of 61.6 on the pro-environmental scale, respondents to the water consultation also demonstrated pro-environmental attitudes and a high adherence to pro-environmental values. On a traditional NEP scale, individuals are considered as having pro-environmental attitudes when they score higher than 45 [502], [520], [521]. Moreover, high pro-environmental scores increase the odds of knowing very well about water scarcity and conservation issues and of considering water as an important issue. Additionally, respondents to the consultation considered themselves as knowledgeable when it comes to environmental and water issues. 76% felt that they had enough knowledge to make well-informed decisions about environmental issues. Similarly, participants to the focus group considered themselves as eco-friendly persons with some of them feeling more strongly about it than others and a large majority of end users involved in the trial phase affirm that they are well-informed about climate change, water scarcity and water conservation.

These positive attitudes are translated into action, as reflected by respondents' report of their low domestic water consumption. Participants indeed reported using showers more often than baths. In fact, the majority of them never or rarely take baths. In line with the 2013 "At Home with Water", they also have efficient washing machines (96%) and they do not start their machine unless it is fully loaded with clothes [58]. The use of dishwasher is also limited in households. Water usage is also limited outdoors, in line with recent statistics that showed that outdoor water consumption in the UK represents only 7% of the average household water use [59]. Overall, basic water-saving habits are also performed in a large number of households (see Table 8-1).

Table 8-1. Reported water-saving habits of the participants to the WISDOM survey.

| Water-saving habits | Reported percentage (%) of participants practicing this habit |
|---|---|
| **Indoor activities** | |
| Not leaving the tap running | 83.3 |
| Doing full loads in dishwashers and washing machines as opposed to doing half loads | 80.3 |
| Taking short showers | 57.6 |
| - Less than five minutes | 24.7 |
| - Five minutes | 27.8 |
| - Between five and ten minutes | 88 |
| **Outdoor activities** | |
| Never washing the car at home | 87.5 |
| Never watering the garden | 77 |
| Collecting rainwater | 50.5 |

Overall, participants' socio-demographic characteristics, their positive attitudes and their reported water usage demonstrate that they are eco-friendly persons. Their awareness of environmental and water issues also suggests that they are inclined to be careful about their daily water consumption and to save water, hinting that the interface could have a positive impact on their consumption.

### 8.1.2. Considering Discrepancies and Contradictions in the Responses Obtained

Despite positive attitudes towards water conservation, discrepancies and contradictions in participants' attitudes emerged from some of the responses obtained. These discrepancies are often discussed in the literature. It is therefore crucial to consider these elements in light of relevant theories (see Chapter 2) and previous studies (see Chapter 3) before drawing conclusions from the results. Thus, this section discusses limitations to the participants' awareness, knowledge and perceived self-identity.

#### 8.1.2.1 Relative Awareness of Domestic Water Consumption

Despite an apparent and self-reported interest in environmental issues and in water conservation, a significant percentage of respondents to the Ask Cardiff and the WISDOM surveys (Appendixes A and B) reported not knowing the amount of water they use. Most participants to the WISDOM survey indeed check the amount they use quarterly or annually with a minority

reporting never checking. The odds of knowing the amount of water used is 9.75 times higher if individuals have a meter than if they do not [460]. However, between 49% and 59% of respondents have a meter installed. This reflects the current situation in the UK where still half of the households were not metered in 2013 [40].

Additionally, the literature affirms that individuals can sometimes mis-estimate their consumption [61], [151], [522]. However, participants to the WISDOM survey correctly assessed the activities on which they use the most water daily. Indeed, for a large majority of them, baths and showers are the activities requiring most water (82.8%), followed by toilet flushes (69.7%), washing machines (51%) and dishwasher loads (38.4%). This is in line with national statistics reporting that a person's daily consumption of water is usually divided between showers or baths (33%), toilet flushes (30%), washing machine (13%) and dishwasher loads (8%)[59].

#### 8.1.2.2. Limited Knowledge of Water Issues

Most respondents to the water consultation (Appendix E) feel that they had enough knowledge to make well-informed decisions about environmental issues. Likewise, end users involved in the trial phase think they are knowledgeable in terms of climate change, water scarcity and water conservation. However, more than a third of the participants to the water consultation admit that they know too little or nothing at all about these issues. In line with this, most experts consider that UK citizens do not have enough knowledge about water issues. This suggests that individuals still need to be more informed about these problems.

In addition, respondents to the consultation are more likely to believe that they will be personally affected by climate change (64%) than by water scarcity (40%). These responses reflect an unawareness of water scarcity issues happening in the UK, such as the ones occurring in South East of England [31], [32], [117]. The non-immediacy of water scarcity in this country indeed limits environmental awareness [130]. The changes happening to water resources in the UK are not noticed and are likely to be noticed only after the human impact has caused severe changes [130]. This lack of knowledge about national water issues is related to the UK's rainy weather and to the prejudices it generates regarding the current state of British water resources [30], [36], [46]. These results therefore reflect a deficit in public knowledge and in the understanding of water issues, as highlighted by the Information Deficit Model [226]–[229].

#### 8.1.2.3. Perceived Pro-Environmental Self-Identity

According to the Cognitive Dissonance Theory and to the Self-Completion Theory described in Chapter 2, the degree to which intention and behaviour is consistent with one's identity determines everyday choices and actions [177], [183]. Conflicts between identity and actions can create a *state of internal tension* [183]. In the context of this project, results show that

respondents care about the environment and have biospheric values. These values are considered as the "stable core" of environmental self-identity and people who care for the environment might want to see themselves as environmentally friendly persons [195]. In line with this, respondents to the water consultation perceive themselves as eco-friendly persons, as shown by their high pro-environmental scores. The overall results obtained from the surveys also demonstrate a reported strong interest in water conservation and environmental issues.

However, despite being interested in reducing water consumption and considering themselves as environmentally friendly, respondents are reluctant to take action. Some of them indeed do not feel that they could do more to save water. More importantly, even self-reported environmentalists are not ready to invest in water-saving devices. This is in line with [223] who affirm that, when it comes to taking action, people often lack motivation or interest and only a few really get involved. Similarly, [183] mentions that, even though most people in western countries are aware of the impact of human action on the environment, active support is difficult to obtain due to a discrepancy between what people believe in and what they do. Despite being concerned about environmental issues, consumers do not change their behaviours accordingly [211].

However, this does not necessarily mean that respondents cannot be considered as environmentally-friendly persons. Indeed, caring for the environment is an attitude that can be translated into multiple actions [130]. Evaluating water-saving activities to assess an environmentally-friendly attitude would therefore be too limited [130]. Respondents might indeed perform a range of other eco-friendly activities in their daily lives.

By identifying water users' level of awareness of their water consumption and attitudes towards water usage, this section has fulfilled Objective 1. On a demographic level, the population's socio-demographic characteristics are line with national statistics and suggest pro-environmental and water-saving attitudes, as described by the literature on the subject [31], [64], [124], [129], [130], [133], [138], [139], [152]. This was confirmed by participants' reported pro-environmental attitudes, beliefs and knowledge regarding water conservation and by their eco-friendly habits at home. However, their awareness of domestic water consumption and knowledge of water issues is more limited in practice than expressed by individuals. Moreover, pro-environmental self-identity and attitudes only motivate water-saving actions to a certain extent. As described in the following section, participants' level of preparedness to use water more sustainably indeed varies among respondents. It is also limited by contextual factors that weaken the influence of attitudes on behaviours. As mentioned in the Attitude-Behaviour-Context Theory and the Value Action Gap

described in Chapter 2, these factors can therefore lead to discrepancies between individuals' perceived self-identity and their actions.

## 8.2. OBJ2: Assess the Current Level of Preparedness for Change Among Water Users.

Respondents' intentions and attitudes influence environmental behaviours, and thus water savings [7], [113], [184], [185]. Moreover, according to the Cognitive Dissonant Theory, individuals strive for consistency within themselves [240], [241]. To be in accordance with their beliefs, results described in section 8.1 therefore suggest that individuals are willing and ready to implement changes in their daily lives to save water. The participants' level of preparedness for change has been assessed through different questions. While they are overall ready to use the interface to reduce their consumption, the results showed that the level of preparedness varies among respondents to the different surveys. Moreover, despite affirming that they are ready to change the way they use water, different factors limit behaviour change in practice. These includes financial concerns, the difficulty to save water at home and the limited interaction with the water supplier.

### 8.2.1. Varied Levels of Preparedness for Change

Some of the results directly demonstrate that individuals are prepared to change the way they use water. Indeed, 86.9% of respondents to the WISDOM survey would be inclined to change their habits to use water in a more sustainable way. This reflects individuals' pro-environmental attitudes towards water conservation as the odds of being willing to change habits are higher if individuals consider water conservation as an important issue than if they do not [460]. In addition, the high pro-environmental score obtained by the respondents to the water consultation also suggest that these individuals are ready to change their water-consuming habits. Indeed, as seen in Chapter 2, while general environmental beliefs are weak predictors of specific water consumption behaviours, they influence specific ecological water beliefs [148]. These specific beliefs directly impact water consumption behaviours [148], [219]. Therefore, by agreeing with general environmental beliefs and with more specific water beliefs, these participants are more inclined to adopt sustainable water behaviours [148], [219]. Among these specific beliefs, a large majority of respondents agreed that they were the type of person who (a) wants to save water, (b) is careful about his/her consumption and (c) does not use water carelessly. The analysis of these results that also showed that, in this sample, an increase in pro-environmental scores increases the odds of (a) being willing to invest in water-saving devices if they were not provided and if there were no short-term benefits and of (b) checking a device that would help reduce water consumption daily or more frequently.

Yet, despite these positive intentions, a large proportion of respondents to the Ask Cardiff survey (67.8%) and to the WISDOM questionnaire (40.9%) consider that they are already doing enough to save water. This contradict experts that largely believe that there is a need to change water users' behaviours and to encourage domestic water savings in the UK. Moreover, this implies that individuals either do not want or do not know how to reduce further reduce their consumption. Yet, only 21.6% of the Ask Cardiff respondents actually stated that they would like to do more to save water. This demonstrates a lack of willingness to do more to save water from the rest of the respondents.

Among those who feel that they do not do enough to save water, 38.9% need guidance to help them save water. This indicates that some individuals need information to further reduce their consumption and suggests that some people might not know how to achieve water savings. Conversely, in the WISDOM survey, 67.2% of respondents would like to do more to save water and almost half of them (47.5%) consider that they need tips and advice to do so. This demonstrates an increased willingness to reduce their consumption and a higher level of preparedness for change compared to the Ask Cardiff respondents.

Regarding the use of the user interface, a large majority of the respondents would be willing to use a device that help them save water. The end users consulted during the trial phase also affirmed that they would be willing to check the interface weekly or monthly while participants to the water consultation would be willing to do so weekly or daily. However, participants to the trial phase in the office setting checked the interface more frequently in practice; several times per week or at least once a week. On another note, participants to the water consultation and to the trial phase reported that they were familiar with the use of new technologies. This implies that they are technically prepared to interact with the interface. The use of the interface is more widely discussed in section 8.4.

### 8.2.2. The Limiting Impact of Contextual Factors

Despite individuals' pro-environmental attitudes, changing water behaviours is limited by different contextual factors including (a) financial concerns that prevent the investment in water-saving devices, (b) the lack of feasible opportunities to reduce their consumption and (c) the limited interaction with the water supplier. According to the Attitude-Behaviour-Context Theory, these contextual forces limit the attitude-behaviour association [16], [113]. If the required behaviours are time-consuming, expensive or difficult to achieve, the impact of attitudes on behaviour is lessened [113]. It is therefore important to take these limitations into consideration and to find solutions to overcome them.

#### 8.2.3.1. Financial Concerns

Despite having an interest in environmental and water-related issues, economic and utilitarian beliefs limit respondents' motivation to use water in a more sustainable way. Respondents are motivated to introduce water-saving habits in their households, but only to a certain extent. The results show that individuals who save water to help the environment or to reduce bills are slightly more likely to be willing to buy and install water-saving devices. Yet, financial concerns prevent respondents from investing in water-saving devices. During the focus group, one of the participants, self-considered as being an eco-friendly person, affirmed that she would be willing to invest in the interface but would not pay over £20 for it. This is coherent with the findings of [63] who came to the conclusion that consumers are often willing to use water-saving devices but would not go as far as buying them [63]. These results are also in line with the Rational Choice Theory that states that individuals choose the options that will give them the greatest satisfaction [220], [221]. Additionally, among the respondents willing to invest, an important proportion would not do so if there was no benefit in the short term. Again, this echoes the Rational Choice Theory that specifies that people's actions are justified by short-term personal benefits [171].

In the context of our study, it can be assumed that individuals do not consider buying water-saving devices as being profitable enough for them to justify the cost and potential installation hassle. Thus, despite having an interest in water conservation, their utilitarian and economic beliefs take over their environmental convictions. By reflecting a difference between participants' attitudes towards water conservation and their actual or intended behaviour, the results reflect a potential 'value-action gap' [130], [209]. Despite being concerned with environmental issues, and reportedly motivated by them, people are not willing to adapt their behaviours accordingly [123], [211]. This demonstrates a conflict of values. Based on the Value Theory (Section 2), by demonstrating financial concerns when it comes to the investment in water-saving devices, the respondents demonstrate the predominance of their hedonic and egoistic values over their biospheric values [88], [179]. In line with the literature, these values therefore restrict their engagement in environmentally-friendly activities, especially in activities that are costly or require efforts [88]. More importantly, according to the Diffusion of Innovation Theory (Section 2.3), this unwillingness to invest would slow the rate of adoption of the interface on a larger scale [176], [265].

As mentioned in Chapter 2.1., it is also worth mentioning that the local weather in Wales does not encourage the investment in water-saving devices the way dry and water-scarce countries do [2], [93], [156], [157].

#### 8.2.3.2. Lack of feasible opportunities to save water

As mentioned in Section 8.2, despite reporting an interest in water conservation, a large majority of respondents believe that they currently do enough to save water. While most respondents to the trial phase questionnaire consider that they have enough opportunities to save water at home, half of them affirmed that it is challenging for them to save water within their household, mostly because of other householders or because they considered themselves as being already efficient. This point was discussed in more depth during the focus group. Participants all agreed on the fact that saving water is difficult. As self-reported eco-friendly persons, they do not know what they can further reduce their consumption at home. A participant highlighted that some water-saving actions, such as reducing the time spent in the shower, decrease the level of comfort. This is in line with the literature that affirms that the performance of pro-environmental actions sometimes results in a loss of comfort for individuals [121], [376], [523], [524]. It was also mentioned that the tips provided by the interface were useful, yet too difficult to put into practice. Additionally, reducing water consumption at the office is even harder than achieving water savings at home due to very limited opportunities for water reductions. Indeed, on average, an employee uses 50 litres for each working day [67]. Thus, only a third of an individual's water usage is at work [67]. Participants' perceived behavioural control, or the belief that the have the ability and resources to save water is therefore limited and hinders the development of water-saving behaviours [7], [184], [185].

[48] affirms that people more easily adopt green behaviours if they do not have to compromise their quality of life. Likewise, it is more difficult to change a behaviour that requires important personal sacrifices [48]. The degree of personal sacrifice required by water-saving habits depends on the activities [48]. Thus, while it is easy to perform some basic water-saving activities, reducing water consumption further might require more important personal sacrifices [48]. In the context of this study, respondents have already adopted basic water-savings habits at home. They take relatively short showers and do not use water for outdoor purposes. Moreover, overall, water consumption in the UK amounts to 150 litres per person and per day [59]. Reducing water consumption in this country therefore implies targeting essential and non-discretionary activities [64], [90], [210]. This suggests that Cardiff inhabitants have less feasible opportunities to save water than people living in countries that use significant amounts of water [55], [57], [59]. Reducing water consumption for them either requires a larger amount of personal sacrifice or the investment in water-saving devices to allow them to reduce their consumption while maintaining a certain level of comfort. This idea of limited opportunities to save water could explain the fact that some of the respondents to the Ask Cardiff survey do not want to more to save water, either by fear of reducing their comfort.

Solutions to this issue includes the provision of water-saving devices to households, as discussed in the following section, or providing individuals with a larger range of easy tips and advice that to save water that do not require a high degree of personal sacrifice nor reduce their level of comfort [39], [90], [104], [108], [329], [356]. Experts believe that changes in policies and regulations on a national level (35.3%), in water-related infrastructure (26.5) could be alternative solutions to encourage water savings in the UK, along with reductions in the consumption of virtual water (29.4%).

As discussed in the next chapter, further research is required to fully understand the impact of the interface on households' consumption over a long period of time. However, while making people more aware of their water consumption might not lead to water savings, due to the lack of feasible opportunities reported by the respondents, increased awareness of their consumption might encourage other environmental activities. There is indeed a possibility for spill-over effects and "catalyst behaviours", as described in Chapter 2.2. [187], [195], [238], [239], [525]. Thus, the interface could go beyond water consumption and have a broader environmental impact.

#### 8.2.3.3. Limited interaction with Water Supplier

Results from the surveys demonstrate a lack of interaction between participants and their water supplier. This needs to be considered as it does not encourage individuals to take action to reduce their consumption.

Most of the respondents only rarely interact with their water company, usually to pay the bills or report a problem. As described in Chapter 3, this reflect the traditional interaction between suppliers and their customers in the UK [526]. While most companies provide information and eco-friendly tips on their website, the majority of respondents reported never or rarely checking their supplier's website [299]–[302]. This can partly explain the fact that most respondents do not feeling encouraged to save water by their water company and are not receiving any regular updates from their supplier water services. In fact, rarely interacting with the supplier and checking the company's website is associated with this feeling of not being encouraged to save water by the water company. However, as discussed during the focus group, while individuals should more frequently consult the supplier's website for information, water companies need to be more pro-active and directly provide tips and advice on how to save water to their customers and better inform them about their consumption. Half of the respondents to the WISDOM survey (52.5%) indeed stated that they would pay more attention to their water use if they were receiving more frequent updates about their consumption, by emails or by post.

During the focus group, water companies were also largely compared to energy suppliers. It was therefore suggested that, just like energy suppliers, water companies should provide free water-

saving devices to their customers. Some participants also mentioned that they would expect their company to pay for the user-interface. In line with recommendations from the UK government, the results obtained therefore suggest that water companies should increase the promotion of water conservation [41]. Increased involvement from water suppliers could better encourage water savings and could be a solution to individuals' reluctance to invest in water-saving devices.

This section fulfilled OBJ2 by assessing the different levels of preparedness for change among respondents. First, the use of the interface as a tool to reduce their consumption is not problematic to participants which suggest that they are technically ready to use it. Their-reported pro-enviromental attitudes and identity also suggest that they are overall ready to change the way they consume water. Yet, it seems that some of them are more inclined to do so than others [240], [241]. This discrepancy in levels of preparedness could result from the sampling method used, as discussed in more details in Section 8.5. However, most respondents are only willing to save water to a certain extent. Even the most eco-friendly participants are not ready to invest in water-saving devices. In addition, some feel that they do not have enough opportunities to save water at home and that they cannot further reduce their consumption. Besides, the limited interaction with their water supplier does not prompt water conservation. Thus, despite positive attitudes, contextual factors limit individuals' actions. This is in line with the Attitude-Behaviour-Context theory, the Knowledge-Action and Value-Action gaps, described in Chapter 2 [113], [187], [312], [484]. Structural changes including increased encouragement and support from water suppliers and the provision of water-saving devices, tips and advice are necessary to encourage individuals to change their behaviours and reduce their domestic water consumption.

## 8.3. OBJ3: Identify the Methods of Encouraging Behaviour Change and Water Savings That are Most Effective across Consumers with Differing Views

In order to better encourage water savings, it is important to identify the methods of behaviour change that have most impact on individuals' consumption. In the context of this study, three different methods e.g. social, financial and environmental, were implemented in the interface. However, as described in the next chapter, it was impossible to efficiently implement the financial and social features in households in the context of this study. This impacted the results obtained and the use of the interface by end users in households and in the office setting, as explained below.

First, in both the Ask Cardiff and the WISDOM surveys (Appendixes A and B), respondents reported that the main reason motivating them to save water was to help the environment. In the Ask Cardiff survey, this was followed by economic considerations. Conversely, the second reason motivating the WISDOM respondents was to reduce wastage. Reducing bills came as the third

reason. This helped understand the aspects of water consumption that interest participants the most. However, the methods of encouraging behaviour change and water savings were actually assessed during the trial phase.

Regarding the features implemented within the interface, the overview of water consumption is the feature that end users would check, or checked, the most (70%), followed by the financial savings (20%), social comparisons (10%) and fact and tips (10%). In line with this and as discussed during the focus group, participants would like to have the choice between monetary units and litres when using the interface. Regarding the tips and advice, participants in the office trial remembered the tips displayed on the interface over the course of the trial. This shows that they read and paid attention to the information provided to them. While it is not possible to verify whether they applied these tips to their everyday life, it indicates that providing such information is useful to educate individuals.

Contrary to the end users' use of the interface, none of the experts believed that the 'overview of water consumption' would capture users' interests. For them, the financial savings tab was most likely to attract attention and to have an impact on water consumption. It seems that experts believe that individuals are more interested in saving water for financial reasons rather than for environmental purposes.

This discrepancy in beliefs between experts and users can be due to different factors. First, as mentioned in section 8.5.1, due to the self-selection sampling method, the respondents to the questionnaire might have pro-environmental attitudes and an initial interest in water consumption that the general public does not have. Therefore, they are not representative of the global population who might be more interested in financial savings, as suggested by experts. Second, this can also be due to the fact that individuals do not know the price they pay for their water usage in the first place. In the Ask Cardiff and the WISDOM surveys, most respondents reported knowing the price of their water usage. Yet, more than half of them indicated that they would be more careful about their water consumption if they were aware of its costs. The contradictions in these responses suggest that people might be aware of the amount of their bills but might not know the specific price of the different water services including in their bills. Confusion and discrepancies regarding the price of water also emerged from the responses to the water consultation. Indeed, while most of the respondents consider that the amount they pay is appropriate to their water usage (68%), they almost equally believe that the price of water is inexpensive (36%), neither expensive nor inexpensive (36%) or expensive (28%). Similarly, experts did not agree on this question and consider that water in the UK is expensive (25%),

neither expensive nor inexpensive (45%) or inexpensive (30%). Thus, the current price of water in the UK is perceived very differently by individuals.

Finally, this discrepancy can also be related to the low price of water in the UK which means that individuals might not be interested in knowing the financial savings they can achieved as these savings do not represent a lot of money. In the context of this study, displaying financial savings for daily or weekly water savings in the interface would not have amounted to a lot of money as water consumption in England and Wales costs just over £1 per day [47], [186]. The estimated financial savings resulting from a 10-litre reduction per day would only amount to a few pennies [47], [186]. This is not enough to motivate individuals to avoid waste and excessive water usage [44]. On the interface, financial savings were therefore estimated over a long period of time to have a more significant impact [355]. While feedback on the financial savings tab from experts and end users has been positive, the focus group revealed that this tab had a low impact on participants in the office setting due to the fact that none of them were paying the bills for this building. Moreover, end users who tried the interface at home did not have it installed in their houses and connected to a meter. Thus, the financial savings displayed were not tailored to their water consumption. As discussed in the following chapter, the impact of displaying these estimated financial savings in households should be further evaluated in future research as the impossibility of fully deploying the interface in a domestic setting limited the impact of this feature in this context.

Similarly to financial savings, the social comparisons feature of the interface could not be properly tested in the context of this project. Yet, by appealing to subjective norms, this method of behaviour change can also encourage water conservation. Indeed, people want to give a positive image of themselves to members of their social group and are influenced by what other thinks and do [176], [178], [179]. According to the Theory of Reasoned Action and to the Theory of Planned Behaviour, these norms indirectly influence the performance of a behaviour by influencing individuals' attitudes and intentions to perform a behaviour [130], [167], [168], [170], [171]. In line with this, a large majority of experts think that people are influenced by their peers when it comes to reducing their water consumption. Yet, most respondents to the water consultation do not feel under social pressure to preserve the environment and did not feel influenced by their peers when deciding to take part in the trial. Most of them are not sure of their peers' expectations regarding environmental behaviours even though they report that these persons protect the environment. To develop a full picture of the impact of social influence on people's water consumption, additional studies would be needed, as explained in the next chapter.

These results helped fulfilling OBJ3 by giving insights as to the methods of encouraging behaviour change that have most impact on users. The fact that participants are interested in the overview of their water consumption and in the financial savings tabs is in line with the rest of the surveys and reflects both their interest in water conservation and their financial concerns. However, implementing the interface in a domestic setting, as suggested in the following chapter, would provide more detailed information about the impact of these features and would efficiently test the influence of the financial savings and social comparisons features on water consumption.

## 8.4. OBJ4: Determine Whether the Use of a Near Real-Time User-Orientated Water Feedback System Promotes Behaviour Change and Water Conservation

A key aspect of this research is the use of a user interface as a tool to promote domestic water conservation. In light of the literature on the subject and based on the results obtained from the experts' consultation, the interface implemented in the trial phase has been designed to encourage water conservation and to make it easier for users to achieve water savings at home and in an office setting (Chapter 6). This section discusses experts' and end users' views on the use of the interface and its impact on water consumption. It also analyses some of the suggestions that were made through the questionnaires and during the focus group.

### 8.4.1. Design and Content of the Interface

According to the Technology Acceptance Model (TAM) described in Chapter 2, the more useful and easy to use a technology is, the more individuals are willing to use it [263]. To increase the acceptance of the user interface, its design has been tailored to ensure that users perceive it as being useful and easy-to-use [263]. The trial phase of the project gave indications as to the views of experts and end users regarding the perceived easiness and usefulness of the interface. The potential use and impact of this tool on water consumption was also assessed during this phase of the project.

For individuals to take action, adopting an innovation needs to generate benefits that are personally relevant to users [176]. The usefulness of the interface was assessed by respondents during the trial phase. Overall, the type of information provided by the interface was appreciated by experts and end users. Respondents reported that the interface provides the right amount of information and enough guidance to reduce water. End users believe that using the interface would make it easy for them to remember to perform water-saving activities. This is important as a behaviour that is easy to acquire is more likely to be adopted [176].

In addition to the perceived usefulness, the perceived ease of use of a technology is crucial to facilitate its acceptance [263]. According to the literature, the presentation of the data needs to

be simple, well-designed and visually attractive [108], [175], [317], [333], [337]. The easiness of the interface and its visual aspect were assessed by experts and end users. A large majority of them reported that the interface was easy to use and visually engaging. Results of the trial phase with end users showed that being familiar with the use of this kind of interface does not change the frequency at which individuals are willing to check the device. However, individuals who are not familiar with the use of the display find it easy to use, this perceived easiness increases the odds of checking the display weekly. Thus, following the TAM, the interface fulfils the criteria of perceived usefulness and easiness as reported by the respondents.

### 8.4.2. Impact of the Interface

According to experts, to have an impact on individuals' consumption, the interface should be used daily or weekly. This is in line with the literature that suggests that feedback should be sent on a daily basis or more frequently to be effective [108], [175], [317], [333]. Indeed, the faster people receive feedback, the most they tend to reduce their water consumption [104]. In the context of this study, end users affirmed that they would be willing to check the interface weekly or monthly and most participants to the trial in the office checked the interface several times per week. Discussion from the focus group however revealed that the location of the display was not ideal. While participants frequently checked the display, it can therefore be assumed that the interface could have been checked even more frequently if it had been installed in a more trafficked area or in a place close to the main source of water consumption in the building [61], [90].

Water experts and end users believe that the interface slightly or moderately increases individuals' awareness of their own consumption. They also largely affirm that using the interface increases the knowledge of water issues and of environmental issues. Similarly, a large majority believe that the interface helps achieving water savings and encourages water conservation in both the long and short term. Yet, during the focus group, the participants highlighted that the use of the interface can fade into everyday life, after novelty wears off. The use of occasional alerts was therefore suggested to maintain users' attention and particularly to inform of excessive water usage. This is in line with the literature that recommends the use of LED displays or sound alarms to notify water consumption spikes [39], [104], [270], [317].

### 8.4.3. Concerns Regarding the Implementation of the User Interface

#### 8.4.3.1. Privacy Concerns

During the trial phase of the interface, some users expressed concerns regarding the privacy of their data. This matter was particularly discussed during the focus group. Participants believe that the collection of their water data by smart meters can be perceived as too intrusive. As demonstrated within the literature, individuals are often concerned about their privacy when using tools such as smart meters, interactive websites or social comparisons [181], [284], [391], [392]. As highlighted during the focus group, individuals also fear that their data could be used for other purposes. As a matter of fact, people tend to be afraid that their data could be forwarded to third parties such as insurance companies, marketers or the police [391], [393], [527]. These concerns are even more apparent when collecting and displaying disaggregated data or "per occupant" data [60], [318]. Additionally, a participant to focus group also stated that his mother '*was always afraid of somebody watching her*'. As [391] affirm, evaluating people's consumption can indeed make them feel like there are under surveillance.

The responses obtained from the participants therefore echoes the attitudes of a part of the population when it comes to the use of smart meters [393]. These concerns hinder people's acceptance of these devices. When implementing these devices, it is therefore crucial to inform users about the protection of their data and to preserve their anonymity as described in Chapter 3.3 [181].

#### 8.4.3.2. Generational Issues

As discussed during the focus group, the use of the interface might not be suitable for everybody. Participants stated that older individuals, who they perceive as being technophobic, might be reluctant to use such tool. However, studies have demonstrated that older generations do not always confirm stereotypes [528], [529]. Results from the trial in an office setting also showed that younger individuals are twice less likely to find the interface easy to use than older individuals. Older adults indeed use technology, especially if it fulfils the requirements of the Technology Acceptance Model, i.e. ease of use and usefulness [528], [530], [531]. Usage of technology among older adults is often encouraged by family members and friends [531]. Thus, the interface should be used and tested by older generations in order to draw conclusions on these generational concerns. However, to adapt it older adults, the appearance of the interface could be slightly modified to include larger fonts and layouts that require less precise movement [532].

This section helped determine whether the use of a near real-time user-orientated water feedback system promotes behaviour change and water conservation, and thus fulfilled Objective

4. The interface received positive feedback and is considered as an adequate tool to encourage domestic water savings. First, the author considers that its use fulfils the requirements from the TAM which implies that the interface is likely to be well-received and used by individuals. Indeed, respondents considered that the interface is useful to increase their awareness of water consumption and their knowledge of water issues and eases the performance of water-savings activities. Moreover, most of them consider that it is easy to use and visually attractive. While improvements regarding its location and its content have been suggested, these initial results demonstrate that the interface can encourage water savings and promote water conservation. However, in order to limit privacy concerns, it is crucial to inform users about the protection of their data when using the interface. Moreover, while the use of the interface is easy for the respondents, future studies could evaluate the use of this tool by older individuals, to ensure that it is adapted to them. This issue was indeed discussed during the focus group and has to be considered.

## 8.5. Methodological Limitations

On a methodological level, this research project has encountered two main limitations. The first one lies in the fact that the selection of the samples studied potentially led to biased responses. Some respondents might have an initial interest in water conservation. Responses from these individuals demonstrate more pro-environmental attitudes than responses from more neutral respondents, e.g. respondents to the Ask Cardiff survey. Thus, most of the participants to this study might not be representative of the global population. The second limitation is related to the fact that attitudes, knowledge, habits and beliefs were self-reported by the participants. Their assessment relies on individuals' perceptions and might therefore be biased.

### 8.5.1. Possible Bias due to the Self-Selection Sampling Method

Due to practical considerations, the author decided to use a non-probability sampling technique known as the self-selection sampling method in the context of this study. The surveys and the water consultation were conducted in agreement with partners to the project. These partners contacted the participants, distributed the online surveys and conducted the water consultation, in line with the questionnaires designed by the author. After being contacted, respondents to the surveys all volunteered to participate in the study. Respondents to the 'Ask Cardiff' survey were also people who volunteered to take part in the annual survey. Emails containing the link to this survey were sent to a random sample of Cardiff inhabitants. These persons then had the choice to answer or not answer the questionnaire and, in that sense, were self-selected. Respondents to the WISDOM questionnaire had agreed to been consulted again in

the 'Ask Cardiff' survey (Appendix A). Respondents to the water consultation had all replied to the letter sent by Welsh Water calling for volunteers. Finally, when responding to the online questionnaire, participants to the trial phase in the office setting had to provide their email addresses if they wanted to take part in the focus group. Concerning the water experts, another non-probability sampling method was used: the snowball sampling method. A number of water experts were contacted and asked to send the online questionnaire to other experts they knew.

The author believes that this lack of probability sampling can therefore limit the generalisation of the results obtained from the surveys. However, these non-probability sampling procedures is often used in qualitative research [413], [449], [450]. The potential limitations affecting the quantitative data obtained from the surveys do not affect the qualitative data obtained from the focus group and structured interviews. Indeed, this data does not intend to be representative but aims at providing a more in-depth understanding of the use of the interface [413], [432].

The self-sampling method used implies that there can be a self-selection bias. Indeed, while the responses obtained from the surveys are relatively similar, it seems that the responses from the 'volunteered' respondents differ from the responses given by the 'Ask Cardiff' respondents. Respondents to the WISDOM survey and to the water consultation and participants to the trial phase indeed demonstrate slightly more environmentally-friendly attitudes when it comes to reducing their consumption than Ask Cardiff respondents. This difference is more apparent between the Ask Cardiff respondents and the WISDOM respondents as the questions asked to both samples led to different answers (see Table 8-2). Contrary to the Ask Cardiff respondents, WISDOM respondents are less likely to consider that they are already doing enough to save water. Most of them would like to do more to save water and almost half of them admit that they need tips and advice to reduce their consumption. Respondents to the WISDOM survey also tend to save water primarily for environmental purposes i.e. help the environment and reduce wastage, whereas many respondents to the Ask Cardiff survey save water to reduce bills.

Table 8-2. Differences in answers between respondents to the Ask Cardiff and WISDOM questionnaires.

| | **Ask Cardiff respondents (%)** | **WISDOM respondents (%)** |
|---|---|---|
| **Would like to do more to save water** | 21.6 | 67.2 |
| **Currently do enough to save water** | 67.8 | 40.9 |
| **Save water to help the environment** | 60.9 | 79.8 |
| **Need guidance to save water** | 38.9 | 47.5 |

The difference between responses from these surveys reflect the positive bias due to the self-selection sampling method used. Indeed, the fact that respondents to the WISDOM survey, to the water consultation and to the trial phase volunteered to be part of the study demonstrates an initial interest in matters related to water consumption. In fact, the average high pro-environmental score of respondents to the water consultation confirm that they adhere to pro-environmental attitudes and beliefs. Regarding the trial phase in an office setting, it is believed that individuals working in this specific office, focused on sustainable engineering, might have an interest in energy or water consumption and suggests that they might be more educated about environmental issues.

Conversely, participants of the Ask Cardiff survey agreed to take part in this survey to express their opinions on their lives in Cardiff. The original intention of this survey was not to question respondents on environmental matters but on the services provided by the city. Therefore, individuals responding to the survey did not know beforehand that it would contained questions related to water consumption. Thus, even though they volunteer to answer the questionnaire, it cannot be asserted that their participation demonstrates an initial interest in environmental or water issues. This explains the lower level of preparedness for change demonstrated by these respondents. This lack of initial interest in water issues also suggests that these individuals represent a more accurate sample of the population. Thus, their responses are likely to echo the beliefs and attitudes of the general public.

However, in spite of this bias, a large majority of respondents to all surveys, consultation and focus group are reluctant to invest in water-saving devices, regardless of their degree of perceived environmental self-identity. By reflecting self-enhancement values, these financial concerns appear to be the main factor limiting individuals' level of preparedness for change.

### 8.5.2. Information Bias due to Self-Reporting

According to the author, another limitation of this study lies in the fact that the attitudes, habits and beliefs assessed in the surveys were self-reported by the respondents. This can also be a source of bias related directly to conscious bias from the person providing the data [533]. Indeed, individuals might intentionally or unintentionally influence the information they provide in order to give a good image of themselves [533]. Individuals' own assessment of their knowledge and awareness of water consumption is subjective and cannot be independently verified. This explains some of discrepancies and contradictions that emerged from the results obtained, as described in section 7.1.4. Indeed, individuals might have mis-estimated their pro-environmental attitudes and knowledge of water issues. Despite demonstrating positive eco-friendly attitudes, respondents' awareness of the amount of water used within households is

limited. Likewise, while they report having knowledge of global water and environmental issues, only a minority show evidence of knowing about water issues. According to the literature, mis-estimation also occurs when individuals are asked to assess their own consumption [61], [151], [522]. It is therefore crucial to consider this limitation in order to draw correct conclusions from the results obtained.

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In light of the literature described in Chapters 2 and 3, this chapter discussed the results from this research project to fulfil to the four research objectives. Yet, due to practical considerations, the present study had limitations. As recommendations for future work and based the findings from this discussion, the next chapter extends the work conducted in the context of this project by describing an 'ideal study' that validate the use of a similar interface in a more adequate setting, based on the relevant literature. While this ideal study do not bring solutions to any of the large-scale contextual barriers aforementioned, i.e. the price of water and the low interaction with water suppliers, implementing the interface differently and in another setting will allow a more in-depth study of the best methods of encouraging behaviour change and will make it possible to evaluate the impact of the interface in households on a longer period of time.

# Chapter 9: Conclusion

To face the current global water crisis, a sustainable use of water resources is required worldwide [2], [3], [5], [6]. Many developed countries are now facing the consequences of this crisis [7]. In the UK, despite heavy rainfalls and the general belief that water resources are abundant, the current population growth and the aging water infrastructure have led to significant periods of drought and flooding [26]–[28], [30]–[32]. Nowadays, a new kind a water management is therefore necessary to deal with these water issues. While increasing the water supply in the UK is considered as a solution to this issue, it generates costs, energy usage, an important carbon footprint and, in some cases, requires the flooding of valleys to form new reservoirs [71], [72]–[76].

Thus, reducing demand appears as an environmentally and economically interesting approach to better manage water resources. This is particularly true as domestic water consumption is a growing concern in the UK with households' water consumption having risen in the past 25 years and now representing half of the public water supply use in England and Wales (52%), [25], [31], [24], [59], [80]. Reducing demand requires the deployment of structural changes at a national level, such as the distribution of water-saving devices and the implementation of pricing measures. However, these changes are currently not deployed in the UK.

This chapter aims at summarizing the main research findings of this research. First, this research has shown in Chapter 1 that the deployment of structural changes would need to be supported by adequate psychological and voluntary measures, as described in Chapter 3, to efficiently promote long-term behaviour change [86], [24], [35], [41]. To do so, it was argued in Chapter 3 that Information and Communication Technologies can be used to deploy both structural and voluntary strategies. While their implementation requires structural changes, these technological advances can indeed promote voluntary behaviour change through the provision of information and feedback on water consumption to inform and educate individuals [28], [105], [109], [110]. However, while many studies on the use of these tools have been conducted in countries affected by water scarcity, there is a lack of research regarding the promotion of behaviour change through ICT to achieve domestic water savings in the UK. The aim of the present research was therefore to study and validate the use of a user-interface, deployed on in-home displays to encourage domestic behaviour change and reduce the water demand in the UK. Based on relevant literature and theories, the following aim was proposed: **'understand whether a user-oriented on-line water feedback system is able to foster improved water-saving behaviours through the promotion of increased awareness of water consumption and the encouragement of positive behavioural and lifestyle changes.'**

To effectively reach this main aim, four research objectives were fulfilled.

- OBJ1: Identify water users' current level of awareness of their water consumption and attitudes towards water usage.
- OBJ2: Assess the current level of preparedness for change among water users.
- OBJ3: Identify the methods of encouraging behaviour change and water savings that are most effective across consumers with differing views.
- OBJ4: Determine whether the use of near real-time user-orientated water feedback system promotes behaviour change and water conservation.

After summarizing the methodology used and the limitations of this research (section 9.1), this chapter explains how these objectives and aim were fulfilled (section 9.2). It concludes this research by setting out recommendations for future work (section 9.3) and implications for practice and policy (section 9.4).

## 9.1. Summary of the Methodology Used

An adequate and robust methodology was followed to fulfil the aim and objectives. By integrating elements from the social sciences and information systems research, the work conducted in the context of this study is interdisciplinary by essence. Thus, the methodology chosen did not follow a traditional approach and did not align with a specific philosophy or specific methodological choices. Instead, the author adopted an interpretivist philosophy, as suggested by social sciences but also integrated elements from a positivist philosophy, as suggested by information systems research. In line with this, it was ensured that the choice of research strategies, including action research, was compatible to these different research philosophies [404]. Following a deductive approach, mixed-methods were used to fulfil the research aim. On the one hand, quantitative methods. i.e. the online questionnaires, helped understand water users' awareness of their water consumption, attitudes towards water conservation and current level of preparedness for change. On the other hand, qualitative methods, i.e. the water consultation (Appendix E), the structured interviews (Appendixes G and I) and the focus group, provided more in-depth knowledge about these attitudes and helped assessing users' experience with the interface.

Following an action research process, the initial surveys (Chapter 5), the literature (Chapters 2 and 3) and relevant theories (Chapter 4) provided baseline information that informed the design of the interface (Chapter 6) to better encourage domestic water conservation. This cyclical research process linked theory and practice by using the knowledge gained from the surveys and

by comparing it against the literature to develop adequate behavioural strategies. In order to reach larger samples of population and in accordance with partners to the project who distributed the questionnaires and conducted the consultation, a self-selection sampling method was used to recruit participants to the surveys. This method is likely to generate biased responses but is however commonly-used in social sciences research [413], [449]–[451]. In this research, it implies that, apart from the Ask Cardiff respondents, participants might have had an initial interest in water consumption. Their responses might therefore reflect a positive environmental bias that is not representative of the global population. In addition, the fact that respondents self-reported their attitudes and water habits is also a potential source of bias as they might intentionally or unintentionally have influenced the information they provided to give a good image of themselves [533]. Finally, the small sample size of the water consultation, of the case study with end users and in the office setting and of the focus group does not allow generalizations. Due to these limitations, the results need to be interpreted with caution. However, they provide a deeper understanding of the use and acceptance of ICT to promote behaviour change and water conservation in the UK.

## 9.2. Fulfilling the Aim and Objectives

The empirical findings in this study, presented in this section, provides a new understanding of the impact of ICT to encourage domestic water conservation in the UK.

**OBJ1. Identify water users' current level of awareness of their water consumption and attitudes towards water usage.**

As mentioned in Chapter 1, governmental initiatives in the UK are lagging when it comes to water conservation. This results in the slow implementation of water meters in the UK. Thus, results described in Chapter 5 demonstrate that participants' awareness of their water consumption is limited as many of them do not have a water meter installed within their household and rarely check the amount of water they use [28], [41], [43]. Yet, despite a rainy weather unfavourable to the promotion of education about water issues, participants to the surveys consider water as an important issue and generally perceive themselves as eco-friendly persons. These positive attitudes are reflected by a relatively low water consumption in households with very limited outdoor water usage, in line with national statistics [59]. Furthermore, most participants report performing basic water-saving activities and avoiding wasting water. A majority also affirm being willing to change their habits and to do more save water. According to the Theory of Reasoned Action and the Theory of Planned Behaviour described in Chapter 2, these positive attitudes participate in encouraging water-saving

behaviours [7], [172], [177], [183], [184]. Moreover water-saving beliefs, as expressed by participants should also lead to water-saving behaviours, as mentioned in Chapter 2 [148], [219].

However, it is important to be cautious when interpreting these results. These attitudes and self-identity might indeed have been influenced by a potential bias resulting from the self-report of the responses, as suggested in Chapter 8. This bias is suspected to have affected individual's reported knowledge of environmental issues. Indeed, people consider that they know about climate change and water scarcity issues. Yet, a large majority believe that they will not be personally affected by these issues. This suggests respondents' lack of knowledge regarding current droughts happening in the UK and water scarcity issues occurring in South-East England. The author considers that this knowledge deficit can however be reduced by the effective provision of information through the interface. Thus, to address OBJ1, water users are currently not all aware of their water usage but demonstrate positive attitudes towards water conservation.

**OBJ2. Assess the current level of preparedness for change among water users.**

Respondents' positive water-saving attitudes, as assessed in Chapter 5, suggest that their level of preparedness for change is high. However, the findings demonstrate that there is an important lack of motivation to invest in a device such as the interface. As mentioned in Chapter 8, individuals' engagement in water-saving actions is indeed limited by hedonic and egoistic values, in spite of a self-reported pro-environmental identity. Even the most eco-friendly respondents are reluctant to invest, as demonstrated in Chapters 5 and 7. Instead, participants expect support from their water suppliers to achieve water savings. This includes the provision of water-saving appliances i.e. the interface and increased encouragement from their supplier. In addition, the level of preparedness for change is also restricted by the low domestic water usage reported by the respondents in Chapter 5. While household's consumption could not be monitored, the activities reported suggest that indoor water activities are limited and probably amount to the average 150 litres used per person per day in the UK [59]. Thus, as mentioned in Chapter 8, there are not a lot of opportunities to save water at home and individuals do not know how to further reduce their consumption. Saving water at work is even more challenging as water consumption is limited to a small number of activities i.e. drinking and toilet flushing. Achieving further water savings therefore implies sacrificing non-discretionary activities and significantly reducing the level of comfort. Due to these factors, the author concludes that participants' level of preparedness for change is low in practice despite positive water-saving attitudes. Therefore, the address OBJ2, water users are ready to change their habits and to use water more sustainably in theory but will not go as far as investing in water-devices or sacrificing their comfort in practice.

**OBJ3. Identify the methods of encouraging behaviour change and water savings that are most effective across consumers with differing views.**

When trying to reduce water consumption and encourage water savings, the literature described in Chapter 3 and results from the initial surveys mentioned in Chapter 5 highlight the need for providing information that appeals to different interests. Thus, the methods of behaviour change implemented within the interface, i.e. social, financial and environmental, aimed at attracting the attention of individuals with different values and concerns, as detailed in Chapter 6. The interface therefore included (a) an overview of water consumption, (b) financial savings that could be potentially achieved by reducing water consumption, (c) social comparisons (d) environmental facts and (e) tips and advice to easily achieve water savings. In line with the respondents' pro-environmental attitudes, Chapters 7 and 8 showed that the overview of the water consumption was the most checked features by end-users at home and in the office setting. Moreover, many participants remembered the tips and advice provided by the interface after the end of the experimentation. In line with the Information Deficit Model evoked in Chapter 2, results from these studies therefore show that providing individuals with information about their consumption is the most effective way to increase awareness and to encourage water conservation [226]–[229].

In line with the Rational Choice Theory and the Prospect Theory described in Chapter 2, the financial savings tab, thought by experts to attract users' interest the most, was also frequently checked [220], [221], [179], [223]. However, the impact of this feature was limited in the context of this study as discussed in Chapter 8. When implemented in the office setting and tried by end users at home, the potential savings had a limited impact as these savings were not directly related to the participants' own bills. Overall, it is believed that the interest in the financial savings is also limited by the fact that many people do not know how much they pay for their water usage in the first place. More generally, the price of water in the UK is relatively low and reductions in water consumption need to be significant in order to achieve money savings [47]. This implies that displaying the actual financial savings achieved might be counterproductive and discourage water conservation efforts.

According to the Social Learning and Social Cognitive Theory and the Theory of Planned Behaviour detailed in Chapter 2, subjective norms encourage behaviours [7], [113], [184], [185]. Yet, Chapters 7 and 8 demonstrated the social comparisons tab also had a limited impact in this study. Individuals reported not feeling under social pressure to save the environment. As suggested by the Other Person Principle, this perception of social pressure might be incorrect. However, the real impact of social influence could not be properly tested because the interface

was not deployed in households and because the office setting was too unique to be compared with other buildings. As mentioned in Chapter 9, these features are however promising and should be considered in future research. Thus, to address OBJ3, the author comes to the conclusion that providing information about users' water usage, such as giving them an overview of their consumption, is the most efficient strategy to increase people's awareness of their water use and promote conservation.

**OBJ4. Determine whether the use of near real-time user-orientated water feedback system promotes behaviour change and water conservation.**

The use of a user-interface as a tool to promote water conservation is promising. As described in Chapter 7 and 8, experts and end users believe it is useful to increase the awareness of water consumption and the knowledge of water issues. It also eases the performance of water-savings activities and is easy to use and visually attractive. The interface fulfils the requirements from the TAM, evoked in Chapter 2, which implies that it is likely to be well-received and adopted by individuals [263], [264]. Thus, these findings demonstrate that the interface can potentially encourage domestic water savings and promote water conservation. However, while the respondents' high pro-environmental score increases their willingness to invest in water-saving devices, the implementation of the interface in households is confronted to a general reluctance to invest in the technology which, according to the Diffusion of Innovation Theory described in Chapter 2, can limit its adoption on a larger-scale [176], [265]. To increase acceptance and investment, it is important to counteract some of the limitations mentioned by the respondents in Chapter 8. Thus, to address privacy and generational concerns, users should be informed about the protection of their data and the interface should be used and tested by older generations [532]. As discussed in Chapter 8, structural changes, such as the provision of the interface by water companies, also seem necessary. To address OBJ4, a near real-time user orientated water feedback system is a useful tool to encourage behaviour change and water conservation.

Finally, it can be concluded that the following research aim has been fulfilled: 'understand whether a user-oriented on-line water feedback system is able to foster improved water-saving behaviours through the promotion of increased awareness of water consumption and the encouragement of positive behavioural and lifestyle changes'. Results of this research project are indeed promising and demonstrate that the use of a user-oriented on-line water feedback system increases individuals' awareness of their water consumption, knowledge of water issues and eases the performing of water-saving activities. Looking at the literature, the author considers that this can encourage a change towards water-saving behaviours. Due to practical considerations, it was not possible to monitor households' water consumption in the context of

this project. Thus, the impact of the interface on households' actual water usage and behaviours could not be assessed. The findings however highlighted that the low level of domestic water consumption in the UK makes it challenging for individuals to save water at home and at the office, despite pro-environmental attitudes. Moreover, the lack of interaction and support from water suppliers and the low price of water in the UK are not favourable to the promotion of water conservation. This leads the authors to suggest recommendations regarding the potential implementation of this tool at a national level.

## 9.3. Recommendations for Future Work

This section presents a recommended methodology, informed and endorsed by the literature, for continuing the work of this thesis into a field deployment that could provide more in-depth information about the use and impact of the interface over an extended period of time (see Table 9-1).

Table 9-1. Validation of the recommended methodology based on the literature.

| **Recommended methodology** | **References** |
|---|---|
| Implementing the interface over a long period of time to build new habits | [338];[130];[175];[192];[193];[337];[108];[104] |
| Using alerts | [317]; [39];[270];[104] |
| Displaying disaggregated data | [317];[175];[64];[90];[108];[364];[322];[270];[91];[379];[318];[53];[60] |
| Displaying personalised information | [333];[108];[91];[104];[332] |
| Providing consequence-based feedback | [334];[335];[90] |
| Displaying financial savings | [206];[221];[113];[339];[220];[164];[267];[352];[318];[108];[214];[270];[104];[254] |
| Social Influence | [168];[167];[130];[485];[253];[208] |
| Displaying social comparisons with similar others | [241];[251];[252];[134];[485];[11];[512];[179];[511];[104];[88] |
| Social media | [206];[113];[330];[208];[214];[177];[186] |
| Impacting self-identity by displaying water data | [247];[170];[230];[130];[226];[228];[150];[235];[234];[211];[195] |
| Gamification | [372];[338];[267];[352];[181];[353] |

### 9.3.1. Practical Implementation of the Interface

The aim of the interface is first to encourage domestic water savings and a change in participants' behaviours. Yet, habits and routine predict behaviours [113], [484]. Thus, behaviour change requires to break old habits and to practice a new behaviour until it becomes a habit [113], [130], [188], [192]. Repeating a behaviour indeed helps to make it automatic [193]. The automacy increases and becomes stable after 18 to 254 days depending on the complexity of the behaviour [193]. Feedback provided over a long period of time participate in the formation of new habits contrary to feedback provided on a short term that leads to less efficient systems [108], [175], [337].

Thus, future studies should implement the interface in households over an extended period of time, ideally over 250 days as suggested by [193]. By taking place over time, with two or more repeated measurements of the same sample of population, these studies would therefore be longitudinal in nature [1], [404], [445]. They would make it possible to evaluate people' attitudes towards water conservation before and after intervention to assess the impact of the user-interface over a specific period of time and to ensure that individuals have enough time to change their behaviours and form new habits. Moreover, to verify the impact of this feedback on water usage, households' water consumption data should be monitored prior, during and after the implementation of ICT and the efficiency of the different methods of behaviour change implemented should be assessed through the monitoring of the use of each feature. Additional questionnaires could also be used to assess participants level of awareness of water consumption and knowledge of water usage prior and after intervention.

Moreover, longitudinal studies would verify whether the use of the interface fades into everyday life, as feared by the participants to the trial phase. They would investigate the frequency of interaction with the interface after a few weeks and could include infrequent alerts informing of abnormal or excessive water usage to determine if such tools can maintain or renew the interaction with the interface to re-motivate water savings [39], [104], [270], [317].

### 9.3.2. Additional Features to Implement and Validate in a Domestic Setting

To extend the knowledge gained in this study about the impact of some features, future studies will could add other features to the interface. Implementing these features at the same time would encourage larger water savings and make it possible to identify the features that have most impact on water consumption. Alternatively, implementing these features separately could also provide useful insights.

As mentioned during the focus group, it was difficult for participants to the trial in the office setting to estimate the impact of their own water usage on the building's overall consumption. Participants therefore stated that the inclusion of disaggregated data within the interface could be useful to understand where and when water is used within the building. While displaying disaggregated data per occupant might raise privacy concerns, users appreciate receiving data regarding specific rooms and appliances [64], [90], [108], [175], [317]. By providing this information, the interface could be used as a learning tool that helps household members identify the "normal baseline" of their consumption and peak usage of water within the house [91], [270], [322], [364]. Moreover, it would give them the possibility to check by themselves the impact of the water-using and water-saving activities that they perform [60], [318]. This would facilitate the identification of the most water-using events and appliances within the house and allow people to target their conservation efforts towards specific activities and devices [53], [90], [318], [366], [379]. The water-saving target tab would then be particularly useful to allow users to set conservation goals for themselves [90], [108], [175], [318], [333], [339], [340]. Collecting disaggregated data would also inform about the effectiveness of the tips and advice provided and about the focus of participants' water conservation efforts [89], [367], [368]. This information can then help improve the design of future conservation measures [89], [367], [368].

The results of the end users and experts' questionnaires showed that financial savings features could have an important impact in people's consumption. Thus, it is recommended that future studies should include a financial savings tab to show householders the amount of money that they can save achieve on their water bills by reducing their water consumption [104], [108], [164], [254], [267], [270], [318], [339]. As described in Chapter 6, due to the low price of water in the UK, the financial savings displayed should be estimations of savings that individuals can achieve in the long term, over a year for instance [355]. Displaying more significant financial savings can indeed lead users to think that they can save a larger amount of money by saving water. Alternatively, it could also be interesting to assess the impact of displaying real financial savings on households' consumption in the UK. While this impact might be limited, as suggested by the literature, evaluating people's reactions i.e. whether they reduce or increase their consumption, could provide useful insights. Additionally, evaluating the impact of the financial features on participant's water consumption would also help determine whether hedonic and egoistic values can positively influence water conservation. This should be assessed in light of the participants' level of income in future studies as this factor can impact house ownership and the willingness to invest in water-saving devices [135], [140].

Future studies should also determine the impact of subjective or social norms on individuals' water consumption. The interface designed in the present study included social features such as

social comparisons with similar households, social ranking between participative households and access to social media. Due to the lack of water consumption data available for buildings like the one in which the trial took place, the deployment of these features was however limited. While respondents' lack of perceived social pressure contradicted experts' opinions on social influence, it cannot be asserted that these persons truly underestimated the influence of their peers since social features could not be implemented in an adequate setting [485]. Future research should therefore implement and validate these features in households and to learn more about the impact of peer pressure and social and reputational aspects on water usage [108], [173], [179], [186], [208], [223], [254], [318], [355]. This could be done by including social comparisons with similar households, access to social media and a social ranking within the interface and by monitoring the number of time these features are checked by users [11], [88], [104], [134], [512]. This could be particularly useful to assess whether subjective norms can encourage water savings, as suggested by the Theory of Reasoned Action and the Theory of Planned Behaviour.

As seen in Chapter 8, respondents consider themselves as eco-friendly persons who want and try to use water in a sustainable way. However, the impracticability of implementing smart meters in households to assess individuals' water consumption made it impossible to verify these statements or to determine whether their self-reported sustainable use of water at home was indeed sustainable. Future studies should therefore determine the impact of the interface and the provision of water consumption data on individuals' self-identity. This self-identity could be verified in light of households' water consumption, as monitored by smart meters, and used as a motivator of sustainable water usage. This could be done through feedback and historical comparisons, as provided by the interface (Chapter 6).

Finally, in future studies, the in-home display implemented could ideally give participants access to a virtual game taking the form of an aquarium. Based on the literature on virtual pets, the aim of the game would be to take care of a virtual fish by making sure the level of water remains high [267], [389], [390]. The level of water could go up and down depending on the household's actual water consumption. In that sense, the game would therefore be pervasive [338], [340], [388]. Each week, participants would also be able to decide on a percentage of reduction to achieve through different objectives that would require the performance of actions such as turning off the tap when brushing teeth or starting the washing machine only when it is fully loaded. By motivating people to develop new daily habits regarding their water use, this game would aim at decreasing households' overall water consumption. It would also help determine whether games can be efficient tools to encourage domestic water savings and to increase individuals' involvement in water conservation in the UK.

## 9.4. Implications for Practice and Policy

The findings of this study have various practical implications. It was demonstrated that the behavioural strategies implemented within the interface increase users' awareness of their consumption and their knowledge of water issues and ease domestic water consumption efforts. This information can be used to develop targeted interventions to promote and educate about water conservation, following the principles of community-based social marketing, as described in Chapter 3.

Implementing the interface in households however requires important structural changes. On a practical level, it necessitates the widespread deployment of smart water meters in the UK. Public reactions to the installation of energy smart meters however hint that such initiative might be confronted to public criticisms based on privacy concerns. These concerns need to be addressed through increased information about the protection of individuals' data. Yet, to better assess public reactions and to evaluate the efficiency of ICT in promoting conservation, the author suggests that an initial roll-out of smart meters, installed in conjunction with informative user interfaces, could be deployed. This could then inform further large-scale conservation initiatives and help counteract negative preconceptions regarding the use of such tools. However, participants' reluctance to invest in the interface, and in water-saving devices at large, suggests that increased support from the government and water suppliers is required to provide the interface to UK households at low cost. Likewise, participants to this study believe that water pricing should depend on the amount of water people use and that their water bill should vary depending on their consumption. Similarly, a majority of experts (47.6%) consider that dynamic pricing can be efficient in the UK. Implementing the interface in conjunction with pricing measures, in the form of adaptive pricing or financial sanctions, could indeed make sustainable water usage more attractive to the general public. While the regulation of water prices by Ofwat in the UK makes it difficult to introduce dynamic pricing in England and Wales, the author believes that the impact of adaptive pricing, similar to energy tariffs, on water consumption in the UK could be usefully evaluated through initial trials [44], [45], [48], [513], [534], [535].

# Appendix A – Questions Included in the 2014 Ask Cardiff Survey

1. Gender

2. Age

3. How many adults, other than yourself, live in your household?

4. How many children live in your household?

5. Children under 4?

6. Children aged 4 – 18?

7. Type of Property

- Owned outright
- Owned with a mortgage
- Private Rented
- Rented from LA
- Other

8. Postcode

9. Electoral Area

10. Are you aware of the amount of water used by you/your household?

- Yes
- No
- Not Sure

11. Do you know how much you pay for your water use?

- Yes
- No
- Not Sure

12. Do you think you would be more careful of your water consumption if you were aware of its costs?

- Yes
- No
- Not Sure

13. Do you feel you are encouraged to save water by the water companies?

- Yes

- No
- Not Sure

14. Do you feel you need guidance to help you save more water?

- Yes
- No
- Not Sure

15. Do you feel that you currently do enough to save water?

- Yes
- No, I would like to do more
- No, I am not interested in saving water
- Not sure

16. What are the reasons motivating you to save water?

- Reduce wastage
- Reduce bills
- Help the environment
- Do not feel motivated to save water
- Other: Specify

17. Do you have any of the following:

- Water Meter
- Lawn or Garden
- External Tap
- Dishwasher
- Rainwater Harvesting Solution
- Solar Water Heating System
- Water-saving Devices
- Other

18. Would you buy willing to buy and install water-saving devices in your house?

- Yes
- No
- Not Sure

# WISDOM End Users

## Welcome

Cardiff Council is working on an exciting project in partnership with a number of different European partners including Cardiff University and Welsh Water to try and better understand the relationship between energy and water. This survey will look at your household consumption, through better understanding how water is used in the household and the interaction you have with the water companies we can look to make savings in water consumption and its associated energy requirements.

For more information about the WISDOM Project, please follow the link: http://www.wisdom-project.eu/

The survey is completed anonymously, can be saved part way through and takes around 15 minutes to compete.

Note that once you have clicked on the CONTINUE button at the bottom of each page you cannot return to review or amend that page.

**Data Protection Statement:**

All data collected in this survey will be held anonymously and securely. No personal data is asked for or retained.

Cookies, personal data stored by your Web browser, are not used in this survey.

# Water consumption questionnaire - WISDOM Project

This survey aims at getting information on people's water-consuming habits in the context of the European WISDOM project.

Questions are 'mandatory' unless marked otherwise.

Note that once you have clicked on the CONTINUE button your answers are submitted and you cannot return to review or amend that page.

## Personal Information

1. Gender

- ○ Male
- ○ Female

2. Age

3. Levelof Education

3.a. If you selected Other, pleasespecify:

4. EmploymentStatus

4.a. If you selected Other, pleasespecify:

5. Postcode

5.a. If you selected Other, pleasespecify:

6. ElectoralArea

6.a. If youselected Other, please specify:

## Home Characteristics

7. Number of adults living in your house?

8. Number of teenagers (>12-18) living in your house?

9. Number of children (<12 years old) living in your house?

10. Home

- Detached
- Semi-detached
- Terraced
- Flat
- Other

10.a. If you selected Other, please specify:

11. Number of rooms (including kitchen, bathroom, toilets, reception and bedrooms)?

12. Home Status

- Rented Private
- Rented Council
- Home
- Other

12.a. If you selected Other, please specify:

13. Do you have any of the following?

- [ ] Water
- [ ] Lawn/Garden
- [ ] External Tap
- [ ] Dishwasher
- [ ] Rainwater Harvesting Solution
- [ ] Solar Water Heating System
- [ ] Spray Tap
- [ ] Water-saving Shower Head
- [ ] Dual Flush Toilets
- [ ] Greywater Shower Heat Recovery
- [ ] Thermostatic Mixer Tap (Taps with inbuilt temperature settings)
- [ ] Other

13.a. If you selected Other, please specify:

14. Would you be willing to install a device to help you save more water?

- ○ Yes
- ○ Yes, but only if the device were free
- ○ No

## Water Usage

*15.*

| | Yes | No | Not sure |
|---|---|---|---|
| Do you consider water conservation as an important issue? | ○ | ○ | ○ |
| Do you think you are currently doing enough to save water? | ○ | ○ | ○ |
| Do you feel you could do more to save water? | ○ | ○ | ○ |
| Would you be willing to buy and install water-saving devices in your house? | ○ | ○ | ○ |
| Do you feel you are encouraged to save water by the water companies? | ○ | ○ | ○ |
| Would you be willing to use water saving devices in your home if they were provided for you? | ○ | ○ | ○ |
| Do you think water pricing should depend on the amount of water people use? | ○ | ○ | ○ |
| Do you think your water bill should depend on your water consumption? | ○ | ○ | ○ |
| Do you feel you need some tips and advice to save more water? | ○ | ○ | ○ |
| Would you be willing to change some of your habits to consume water in a more sustainable way? | ○ | ○ | ○ |
| Do you ever check the water quality within your house? | ○ | ○ | ○ |

*16.* Areyouawareoftheamountofwaterthatyouuse?

○ Yes ○ No ○ Not Sure

17. If not, do you think you would be more careful of your water consumption if you were aware of its costs?

- Yes
- No
- NotSure

18. Whatimportance do you give to water conservation in your daily life?

- Veryimportant
- Important
- Neitherimportantnorunimportant
- Unimportant
- Very unimportant

19. Whatare the reasons motivating you to save water?

- [ ] Reducebills
- [ ] ReduceWastage
- [ ] Help the environment
- [ ] I do not feel motivated to save water
- [ ] Other

19.a. If you selected Other, pleasespecify:

20. How often do you check how much water you have been using?

- ○ Daily
- ○ Weekly
- ○ Monthly
- ○ Quarterly
- ○ Annually
- ○ Never

21. On average, how much per month do you pay for your water?

- [ ] <£20
- [ ] £20- £30
- [ ] £30-£40
- [ ] £40-£50
- [ ] £50-£60
- [ ] >£60
- [ ] Not sure

22. What kind of water-saving habits do you have within your household?

- [ ] Short Showers
- [ ] Full loads dish/clothes washers
- [ ] No taps left running
- [ ] Other

22.a. If you selected Other, please specify:

## Water Supply and Interaction with Water Companies

23. Who supplies your water?

- Welsh Water
- Not Sure
- Other

23.a. If you selected Other, please specify:

24. How do you pay your water bills?

- Direct
- Credit/Debit Card
- Other

24.a. If you selected Other, please specify:

25. How do you interact with your water company?

26. Do you receive regular updates about your water, including quality, service improvement, etc...?

- Yes
- No

27. Do you feel you could be more careful about your water usage if you received more frequent updates about your consumption?

- Yes
- No

28. How would you like to receive these updates?

- ☐ Post
- ☐ Email
- ☐ Phone
- ☐ Mobileapplication
- ☐ Webapplication
- ☐ Other

28.a. Ifyou selectedOther, pleasespecify:

29. Whydoyou interactwithyour watercompany?

- ☐ PayBills
- ☐ ReportProblems
- ☐ Complainaboutbills
- ☐ RequestInformation
- ☐ Idon'tinteractwith mywatercompany
- ☐ Other

29.a. Ifyou selectedOther, pleasespecify:

30. How do you rate your water company website?

- ○ Veryuseful and informative
- ○ Average
- ○ Notusefulatall
- ○ Not sure

31.

| | Often | Few times a year | Rarely | Never |
|---|---|---|---|---|
| How often do you interact with your water company? | ○ | ○ | ○ | ○ |
| How often do you consult your water company website? | ○ | ○ | ○ | ○ |

32. Doyouever collectrainwater?

○ Yes ○ No ○ Notsure

33. Ifso,what do you use rainwaterfor?

**Daily Consumption**

34. On what daily activities do you use the most water?

- [ ] Baths/Showers
- [ ] Toilet flushes
- [ ] Drinking/Cooking
- [ ] Dish washing
- [ ] Washing Machines
- [ ] Other

34.a. If you selected Other, please specify:

| 35 | Daily Activities |
|---|---|
| How many baths are taken per day within your house? | |
| How many showers are taken per day within your house? | |
| How many sinks of water do you use per day for dish washing by hand? | |
| How many toilet flushes per person per day? | |

36. How many minutes does an average shower last within your household?

37. Is your shower is equipped with a thermostatic mixer tap?

- Yes
- No
- Not Sure

38. If so, which temperature is set?

38.a. If you selected Other, please specify:

| 39 | Weekly Activities | |
|---|---|---|
| How many dishwasher loads do you use per week? | | |
| How many washing machine loads do you use per week? | | |
| How many times per week (in the summer) do you use tap water for garden purposes? | | |

40 What is the normal temperature setting that you use on your washing machine?

40.a. If you selected Other, please specify:

# Thank you

Thank you for your cooperation in completing this questionnaire. For more information about the WISDOM project: **http://www.wisdom-project.eu/**

Please follow this link to return to the:

**Bristol Online Surveys Homepage**

**Key for selection options**

**2 - Age**

Less than 18
18 - 30
31 - 50
50 +

**3 - Level of Education**

Primary School
Secondary School
Six Form/College/Vocational Training
Diploma
Advanced Diploma
University Degree
Postgraduate Qualification
Other

**4 – Employment Status**

Student
Employed
Self-employed
Business Owner
Retired
Unemployed
Other

**5 - Postcode**

CF3
CF5
CF10
CF11

CF14
CF15
CF23
CF24
CF30
Other

**25 – How do you interact with your water company?**

Phone
Online
Letter
Mobile App
Other

**37 - Is your shower is equipped with a thermostatic mixer tap?**

Yes
No

**38 - If so, which temperature is set?**

Cold Shower
36°C
37°C
38°C
39°C
40°C
Not sure
Other

**40 - What is the normal temperature setting that you use on your washing machine?**

30°C
40°C
50°C
60°C
70°C
80°C
90°C
Not Sure
Other

# Water Experts Consultation

## Page 1: Introduction

***This questionnaire has been created in the context of a PhD research project, that is part of the EU FP7 WISDOM project. This project aims at (a) increasing user awareness and modifying behaviours concerning the use of water, (b) achieving quantifiable reduction in water consumption and (c) reducing peak-period of water distribution loads by using Information and Communication Technologies (ICTs).***

This questionnaire is divided in two main sections. The first section focuses on the consumption of water in European households while the second section is related to domestic water consumption in the United-Kingdom.

These questions are related to (a) people's knowledge of water issues, (b) the best ways to encourage water savings and behaviour change, (c) the role of social influence or the role that others can have on one's water consumption and (d) the use of new technologies to promote water savings.

The responses will be collected for advisory purposes. For more information about the WISDOM project, please visit: http://www.wisdom-project.eu/

Thank you for your cooperation.

# Page 2: Page 1

## Personal Information

1 Domain of Expertise:

- [ ] Water
- [ ] Energy
- [ ] Other

1.a. If you selected Other, please specify:

2. What is your field of work?

- ○ Academia
- ○ Industry
- ○ Other

2.a. If you selected Other, please specify:

3. Place of Residence:

3.a. If you selected Other, please specify:

## Water Consumption Around the World

4. In your opinion, changing water users' behaviours can be a solution to current water scarcity issues in developed countries.

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

5. In your opinion, how much influence do the climatic conditions of a country have on people's awareness of water issues?

- Very influential
- Influential
- Somewhat influential
- Not at all influential

6. In your opinion, are people influenced by their peers when it comes to reducing their water consumption?

- Very much influenced
- Influenced

- Somewhatinfluenced
- Notatallinfluenced

# Page 3

## Water Consumption in Europe

Please answer the following questions if you live in Europe or have an opinion on the subject of water consumption in Europe.

*7.* In your opinion, European citizens have enough knowledge about water issues?

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

*8.* In your opinion, using Information and Communication Technologies (in-home displays and mobile/tablet applications) can increase people's knowledge of their water

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

*9.* In your opinion, how important is it to encourage domestic water savings in Europe?

- Very important
- Important
- Neither important nor unimportant
- Unimportant

10. In your opinion, what are the most efficient ways to encourage water savings in the Europe?

- [ ] Changes in water distribution and recycling infrastructure
- [ ] Changes in policies and regulations at national and EU levels
- [ ] Changes in policies and regulations on an international level
- [ ] Changes in users' behaviours within their households
- [ ] Changes in users' behaviours (to reduce the consumption of virtual water i.e. the water used in the industrial or agricultural processes)
- [ ] Other

10.a. If you selected Other, please specify:

11. In your opinion, there is a need to change water users' behaviours in Europe.

- ○ Strongly agree
- ○ Agree
- ○ Neither agree nor disagree
- ○ Disagree
- ○ Strongly disagree

12. In your opinion, encouraging behaviour change in Europe can efficiently reduce water

- ○ Strongly agree
- ○ Agree
- ○ Neither agree nor disagree
- ○ Disagree
- ○ Strongly disagree

13. In your opinion, what are the most efficient ways to trigger behaviour change and environmentally friendly behaviours in Europe?

- [ ] Financial incentives, rewards and punishments
- [ ] Time-based pricing programs in which customers are charged based on the time of day that water is consumed.
- [ ] Social pressure
- [ ] Information and education about environmental issues
- [ ] Information and education about the links between water and energy usage
- [ ] Information and education about the water used in the industrial or Agricultural processes
- [ ] Other

13.a. If you selected Other, please specify:

*14.* In your opinion, what are the barriers preventing behaviour change in Europe?

- [ ] Economic and financial barriers (price of water-saving devices, etc.)
- [ ] Weather and climatic conditions
- [ ] The price of water
- [ ] Lack of knowledge about water issues
- [ ] Lack of regulations and governmental initiatives
- [ ] Other

*14.a.* If you selected Other, please specify:

*15.* In your opinion, using Information and Communication Technologies (in-home displays and mobile/tablet applications) can encourage water savings.

- ○ Strongly agree
- ○ Agree
- ○ Neither agree nor disagree
- ○ Disagree
- ○ Strongly disagree

16. In your opinion, using Information and Communication Technologies (in-home display and mobile/tablet applications) can encourage behaviour change.

- ○ Strongly agree
- ○ Agree
- ○ Neither agree nor disagree
- ○ Disagree
- ○ Strongly disagree

17. In your opinion, which type of user-interface is the most effective to promote behaviour change and inform water users?

- ☐ Applications on smartphones and tablets
- ☐ Web applications on personal computers
- ☐ In-home displays
- ☐ Other

17.a. If you selected Other, please specify:

# Page 4

## Water Consumption in the United-Kingdom

Please answer the following questions if you live in the United-Kingdom or have an opinion on the subject of water consumption in the UK.

*18.* In your opinion, UK citizens have enough knowledge about water issues.

- ○ Strongly agree
- ○ Agree
- ○ Neither agree nor disagree
- ○ Disagree
- ○ Strongly disagree

*19.* In your opinion, using Information and Communication Technologies (in-home displays and mobile/tablet applications) can increase people's knowledge of their water.

- ○ Strongly agree
- ○ Agree
- ○ Neither agree nor disagree
- ○ Disagree
- ○ Strongly disagree

*20.* In your opinion, how important is it to encourage domestic water savings in the UK?

- ○ Very important
- ○ Important
- ○ Neither important nor unimportant
- ○ Unimportant

21. In your opinion, what are the most efficient ways to encourage water savings in the UK?

- [ ] Changes in water-related infrastructures
- [ ] Changes in policies and regulations on a national level
- [ ] Changes in policies and regulations on an international level
- [ ] Changes in users' behaviours within their households
- [ ] Changes in users' behaviours (to reduce the consumption of virtual water)
- [ ] Other

21.a. If you selected Other, please specify:

22. In your opinion, there is a need to change water users' behaviours in the UK.

- ○ Strongly agree
- ○ Agree
- ○ Neither agree nor disagree
- ○ Disagree
- ○ Strongly disagree

23. In your opinion, encouraging behaviour change in the UK can efficiently reduce water consumption.

- ○ Strongly agree
- ○ Agree
- ○ Neither agree nor disagree
- ○ Disagree
- ○ Strongly disagree

24. In your opinion, what are the most efficient ways to trigger behaviour change and environmentally friendly behaviours in the UK?

- [ ] Financialincentives,rewards andpunishments
- [ ] Time-basedpricingprograms inwhichcustomersarechargedbasedon thetimeofdaythatwateris consumed
- [ ] Socialpressure
- [ ] Information andeducationaboutenvironmentalissues
- [ ] Information andeducationaboutthelinks betweenwater andenergy usage
- [ ] Information andeducationaboutthewater usedintheindustrialor Agriculturalprocesses
- [ ] Other

24.a. If you selected Other, please specify:

25. In your opinion, what are the barriers preventing behaviour change in the UK?

- [ ] Economicandfinancialbarriers (priceofwater-savingdevices,etc.)
- [ ] Weather anddimaticconditions
- [ ] Thepriceofwater
- [ ] Lackofknowledgeaboutwaterissues
- [ ] Lackofregulations andgovernmentalinitiatives
- [ ] Other

25.a. If you selected Other, please specify:

26. In your opinion, using Information and Communication Technologies (in-home displays and mobile/tablet application) can encourage water savings?

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

27. In your opinion, using Information and Communication Technologies (in-home displays and mobile/tablet applications can encourage behaviour change.

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

28. In your opinion, which type of user-interface is the most effective to promote behaviour change and inform water users.

- [ ] Applications on smartphones and tablets
- [ ] Web applications on personal computers
- [ ] In-home displays
- [ ] Other

28.a. If you selected Other, please specify:

29. What do you think of the price of water in the UK?

- ○ Expensive
- ○ Slightly expensive
- ○ Neither expensive nor inexpensive
- ○ Slightly inexpensive
- ○ Inexpensive

30. Dynamic pricing (depending on the time of day, week and/or season) can be efficient in the UK?

- ○ Strongly agree
- ○ Agree
- ○ Neither agree nor disagree
- ○ Disagree
- ○ Strongly disagree

**Thank you for taking part in this survey.**

For more information about the WISDOM project: http://www.wisdom-project.eu/

**Key for Selection Options**

**3 - Place of Residence:**

- United-Kingdom
- Western Europe
- Northern Europe
- Southern Europe
- Eastern Europe
- America
- Asia
- Middle East
- Australia
- Africa
- Other

# Appendix D – Letter from Water Supplier

Hello,

**We'll be putting in new smart water meters in your area shortly.**

This may include changing the meter in your home. Don't worry, when we are changing your meter, we don't need to do anything and it won't cost you a penny. One of our meter installation contractors will contact you personally if we plan to upgrade your meter.

**But, we're also looking for volunteers…**

Alongside this, we are looking for volunteers in the area to take part in a project called WISDOM, which will involve us looking at your water usage through your smart meter data. This will also include a free water audit of your home and the opportunity to receive free water efficiency products and if you choose to be fully involved in the project, we will thank you with an incentive.

This project is funded by the European Commission and aims to help us better understand how people use water in their home.

Volunteering to be involved in this project will be a huge help for us to better understand how people in Wales use water.

**Willing to volunteer?**

Send us an email to wisdom@dwrcymru.com with your name, address and telephone number

Once we have heard from you, we will then contact you to arrange a suitable time to come and visit your house, undertake the water audit and provide you with more information on how to be involved in the project.

Thanks for your time

Andy Blackhall

# Appendix E – Water Consultation (Households)

## General

- Where is the nearest electricity plug point?
- Where is the customer's energy meter? (take picture)
- Is there a energy smart meter?
- Interested in becoming involved in 'Type 2' house activity? *More invasive retro-fit/in house displays etc.*
- Incentives: what would customer prefer: Voucher/Tablet/Gift Voucher

## Water Efficiency

- Would you be willing to invest in water-saving devices if they weren't provided for you?
- If yes, how much more would you be willing to pay/ how much would you be willing to invest?
- Would you be willing to invest in water efficiency audit?
- Are you aware of other water saving devices?
- Would you invest in water efficiency devices even though there were no direct benefits in the short term?

## Technologies

- Do you have a computer?
- Do you have a Smart Phone?
- Do you have Wifi?
- How familiar are you with the use of social media (Facebook, Twitter, Instagram…)?
- How often do you use social media?
- Do you play online games - computer and/or phone?
- How familiar are you with the use of new technologies?
- What technologies are you familiar with? Laptop, computer, mobile app, web app, smart phone. tablet, none
- What method to view data does customer prefer? Tablet, apps, internet webpage
- How often would you be willing to check it a device that would help you reduce your consumption?

| *Never* | *Rarely* | *Annually* | *Monthly* | *Weekly* | *Daily* | *A Few Times a Day* |
|---|---|---|---|---|---|---|
| | | | | | | |

- How often would you like to receive updates about your consumption?

| *Never* | *Rarely* | *Annually* | *Monthly* | *Weekly* | *Daily* | *A Few Times a Day* |
|---|---|---|---|---|---|---|
| | | | | | | |

## Water Pricing

- Do you think your water bill is appropriate to the amount of water you use?
- What do you think of the price of water in the UK?

| | | | | |
|---|---|---|---|---|
| *Very inexpensive* | *Slightly inexpensive* | *Neither expensive nor inexpensive* | *Slightly expensive* | *Expensive* |

Environmental Knowledge and Beliefs

***5-point scale: 5- strongly disagree, 4 - disagree, 3 - neither agree nor disagree, 2 - agree, 1 - strongly Agree***

- 'Making people more aware of how their behaviour affects the environment, water conservation encourages more environmentally-friendly behaviour'
- 'People who care about the environment tend to reduce their water consumption'
- 'Water savings should be mandatory'
- 'Water conservation can help tackle climate change'
- 'I am a person who endorses a green lifestyle'
- 'I think of myself as someone who is very concerned with environmental issues'
- 'Water Conservation is an important issue'
- 'I would like to join and actively participate in an environmentalist group'
- 'Whenever possible, I try to save natural resources'
- 'I am the type of person that is careful about his/her water consumption"
- 'I am the type of person who wants to save water"
- 'I am not the type of person to use water carelessly"
- 'Most people who are important to me want me to be environmentally friendly'
- 'Most people who are important to me protect the environment'
- 'I feel under social pressure to preserve the environment'
- 'I feel I have enough knowledge to make well-informed decisions on environmental issues'

***5 point scale: 5 - not at all influential, 4 - slightly influential, 3 - somewhat influential, 2 - very influential, 1 - extremely influential***

- How much impact did the views of your family/friends/colleagues have on your decision to participate in this experiment and possibly reduce your water consumption?

***4-point scale: 4 - not important, 3 - Somewhat Important, 2 - Important, 1 - very important***

- How important is the issue of climate change to you personally?
- 'How important is the issue of water scarcity to you personally?'
- 'Do you think climate change is something that is affecting or is going to affect you, personally?'

- ‘Do you think water scarcity is something that is affecting or is going to affect you, personally?’

***6-point scale: 6 - Not at all, 5 - too little, 4 - Fairly well, 3 - Quite well, 2 - Very well, 1 – Perfectly***

- ‘How much, if anything, would you say you know about climate change’
- ‘How much, if anything, would you say you know about water scarcity/conservation?’

# Experts Questionnaire - User Interface

This questionnaire aims at collecting water experts' views on the use of an interactive user-interface (an informative screen provided on webpages and applications). The objective is to understand whether the use of this interface could help people save water at home and change their behaviours regarding water consumption. This interface will be available on in-home displays, web and mobile applications.

**Prior to completing the questionnaire, please have a look at the mock-up interface, representing a typical household's consumption, on http://cardiff.wisdomproject.eu using the username 'wisdom70' and the password 'wisdom321'.**

Examples of other facts include: 'Did you know that UK households use 50% more water than 25 years ago?' - 'Did you know that the production of a cotton t-shirt requires the equivalent of 25 full baths of water?' - 'Did you know that letting the tap run while brushing your teeth can waste over 6 litres of water per minute?'
Examples of other tips include: 'Today, turn off the tap when soaping or washing your hair in the shower' - 'Try not to brush your teeth in the shower. It can waste up to 30 litres of water' - 'Only fill the kettle with the amount of water needed'

The responses will be collected for advisory

purposes. Thank you for your cooperation.

1. Domain of Expertise:

- ○ Water
- ○ Energy
- ○ Other

1.a. If you selected Other, please specify:

2. Field of Work:

- Academia
- Industry
- Other

2.a. If you selected Other, please specify:

3. Place of Residence:

- United Kingdom
- Northern Europe
- Southern Europe
- Western Europe
- Eastern Europe
- Other

3.a. If you selected Other, please specify:

4. How would you describe the use of the interface?

- Very easy
- Relatively easy
- Relatively challenging
- Very challenging

5. In your opinion, is the design of the interface visually engaging?

- Yes
- No

6. What suggestions do you have, if any, for improving the design of the interface?

7. Please evaluate the impact of the interface:

| | No (0) | +1 | +2 | Yes, a lot (+3) |
|---|---|---|---|---|
| In your opinion, can the interface increase users' awareness of their water consumption? | ☐ | ☐ | ☐ | ☐ |
| In your opinion, can the use of the interface increase users' | ☐ | ☐ | ☐ | ☐ |

| | | | | |
|---|---|---|---|---|
| awareness of water issues? | | | | |
| In your opinion, can the use of the interface increase users' awareness of environmental issues? | ☐ | ☐ | ☐ | ☐ |
| In your opinion, does the interface offer users enough guidance to reduce their water consumption? | ☐ | ☐ | ☐ | ☐ |

8 In your opinion, can the interface encourage users to save water?

- ○ Yes, in both the short and long term
- ○ Yes but only in the short term
- ○ Yes but only in the long term
- ○ No

9. In your opinion, the interface provides...

- ○ ...Too little information about users' consumption
- ○ ...The right amount of information about users' consumption
- ○ ...Too much information about users' consumption

10. How frequently do you think the device should be used to have an impact on users' consumption?

- Several times per day
- Once per day
- Several times per week
- Once per week
- Several times per month
- Once per month
- Less than once per month

11. In your opinion, which feature is more likely to capture users' interest?

- Overview of Water Consumption
- Comparisons and Social Ranking
- Financial Savings
- Facts, Tips and Advice

12. Assess the following features according to the impact you think they have on people's consumption.

| | No impact | Low impact | Moderate impact | High impact |
|---|---|---|---|---|
| Overview of Water Consumption | ☐ | ☐ | ☐ | ☐ |
| Comparisons and Social Ranking | ☐ | ☐ | ☐ | ☐ |
| Financial Savings | ☐ | ☐ | ☐ | ☐ |
| Facts, Tips and Advice | ☐ | ☐ | ☐ | ☐ |

13. In your opinion, what are the positive aspects of the interface?

14. In your opinion, what are the negative aspects of the interface?

15. What suggestions do you have, if any, for improving the content of the interface?

16. Please assess the following statements:

Please don't select more than 1 answer(s) per row.

| | Strongly agree (+2) | +1 | 0 | -1 | Strongly disagree (-2) |
|---|---|---|---|---|---|
| Technology is my friend. | ☐ | ☐ | ☐ | ☐ | ☐ |
| I enjoy learning new computer programs/apps and hearing about new technologies. | ☐ | ☐ | ☐ | ☐ | ☐ |
| People expect me to know about technology and I don't want to let them down. | ☐ | ☐ | ☐ | ☐ | ☐ |

| | | | | | |
|---|---|---|---|---|---|
| If I am given an assignment that requires that I learn to use a new program or how to use a machine, I usually succeed. | ☐ | ☐ | ☐ | ☐ | ☐ |
| I relate well to technology and machines. | ☐ | ☐ | ☐ | ☐ | ☐ |
| I am comfortable learning new technology. | ☐ | ☐ | ☐ | ☐ | ☐ |
| I know how to deal with technological malfunctions or problems. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Solving a technological problem seems like a fun challenge. | ☐ | ☐ | ☐ | ☐ | ☐ |
| I find most technology easy to learn. | ☐ | ☐ | ☐ | ☐ | ☐ |
| I feel as up-to date on technology as my peers. | ☐ | ☐ | ☐ | ☐ | ☐ |

*16.a.* If 'technophobia' is defined as feeling discomfort about smartphones / apps or any new technology, which of the following best describes you?

- Highly technophobic (+3)
- +2
- +1
- Not technophobic (0)

**Thank you for your participation**

This questionnaire has been created in the context of a PhD research project, that is part of the EU FP7 WISDOM project.

This project aims at (a) increasing user awareness and modifying behaviours concerning the use of water, (b) achieving quantifiable reduction in water consumption and (c) reducing peak-period of water distribution loads by using Information and Communication Technologies (ICTs).

For more information about the WISDOM project, please visit: http://www.wisdom-project.eu/

# Final Questionnaire - User Interface

## Water consumption and use of the display

1. Estimate your household'swater consumptionbeforethe start of the experiment.

- Higherthanaverage
- Average
- Lowerthanaverage

2. Are you familiarwith this kind of display/application?

- Yes
- No

3. How easy do you think it would be for you to use the display?

- Verychallenging
- Challenging
- Relativelyeasy
- Veryeasy

4. How often would you be willing to check the device?

- ○ Several times per day
- ○ Once per day
- ○ Several times per week
- ○ Once per week
- ○ Several times per month
- ○ Once per month
- ○ Less than once per month

5. Which features of the device do you think you would check the most?

- ☐ Your water usage information (overall consumption and water savings)
- ☐ The comparisons tabs
- ☐ The facts and tips
- ☐ The financial savings
- ☐ Other

5.a. If you selected Other, please specify:

6. Usage of the display

Please don't select more than 1 answer(s) per row.

| | Strongly agree | Agree | Disagree | Strongly disagree |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Using the display would enable me to achieve water savings. | ☐ | ☐ | ☐ | ☐ |

| | | | | |
|---|---|---|---|---|
| Using the display would encourage me to save water. | ☐ | ☐ | ☐ | ☐ |
| Using the display would make me more aware of my water consumption. | ☐ | ☐ | ☐ | ☐ |
| The display provides helpful guidance in performing water-saving activities. | ☐ | ☐ | ☐ | ☐ |
| Overall, I find the display easy to use. | ☐ | ☐ | ☐ | ☐ |

*7.* How easy is it to save water at home for you?

- ○ Very easy
- ○ Relatively easy
- ○ Challenging
- ○ Very challenging
- ○ Other

*7.a.* If you ticked 'Challenging' or 'Very challenging', please explain.

8. Do you think you have enough opportunities to save water at home?

- Yes
- No

8.a. Pleaseexplain:

9. Would it be easy for you to remember to perform water-saving tasks using the display?

- Very easy
- Moderately easy
- Slightly easy
- Not at all

10. What are the positive aspects of the device?

11. What are the negative aspects of the device?

12. Do you have any suggestions on how the interface could be improved?

## Knowledge of Environmental and Water issues

13. Would the use of the interface increase your knowledge of water issues?

- Yes, a lot
- Yes, marginally
- No

14. Would the use of the interface increase your knowledge of environmental issues?

- Yes, a lot
- Yes, marginally
- No

## 15. Knowledge of Climate Change & Water Scarcity

Please don't select more than 1 answer(s) per row.

| | Perfectly | Very well | Quite well | Fairly well | Too little | Not at all |
|---|---|---|---|---|---|---|
| How much, if anything, would you say you know about climate change? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| How much, if anything, would you say you know about water scarcity/conservation? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

# Appendix H – Email Invitation to Participate in the Trial (Office Setting)

Dear all,

As some of you may have noticed, an in-home display has been installed on the wall next to the meeting room this morning.

This display has a number of different features:

- It shows you the hourly water consumption of 52 The Parade (in litres).
- It gives you the possibility to compare the building's current and past water usage.
- It provides you every day with new tips and facts on how to reduce your water consumption (in the office and/or at home!).

**Please do check it as often as you want to tract the building's water consumption or simply to learn more about water conservation and how to reduce your daily water consumption.**
**This display will remain in the building until Tuesday, the 1st of August. After that, you will receive a short questionnaire to fill in.**

Please note that some of the features have been designed to be implemented in households and are less adapted to a working building like 52 The Parade. The 'water saving goal', 'social ranking' and 'comparisons with others' features are therefore not tailored to 52.

*This study is part of my research project, conducted in the context of the WISDOM project. The WISDOM project aims at (a) increasing user awareness and modifying behaviours concerning the use of water, (b) achieving quantifiable reduction in water consumption and (c) reducing peak-period of water distribution loads by using Information and Communication Technologies (ICTs).*

If you have any enquiries or if you want to report any technical problems, please contact me directly.

Thank you very much for your cooperation!

## Email Reminder After a Week

Dear all,

Just to remind you that the in-home display (next to the meeting room) will stay in 52 The Parade for another week only.
Please, feel free to check it if you haven't done so already. This display:

- shows you the hourly water consumption of 52 The Parade (in litres).
- gives you the possibility to compare the building's current and past water usage.
- provides you everyday with new tips and facts on how to reduce your water consumption (in the office and/or at home!).

If you have any enquiries or if you want to report any technical problems, please contact me directly.
Many thanks!

# Questionnaire - 52 The Parade

This questionnaire aims at collecting your views on the use of the interactive display that was installed at 52 The Parade between the 18th of July and the 1st of August 2017.

The objective is to understand whether the use of this interface could help people save water at home and change their behaviours regarding water consumption. This interface will be available on in-home displays, web and mobile applications in selected households in Cardiff.

Thank you very much for your cooperation!

I am...

- a PhDstudent
- a postdoctoral researcher
- Other

If you selected Other, please specify:

Age

- 20-25
- 26-35
- 36-45
- 46 +

Country of Origin

Did you have a look at the display over the past two weeks?

- Yes
- No

How often did you check the display over the past two weeks?

- Once in the past two weeks
- Once a week
- Several times a week
- Once a day
- Several times a day

What was the reason for not checking the display?

- I wasn't at 52 The Parade
- I forgot
- I wasn't interested
- Other

If you selected Other, please specify:

How would you describe the use of the interface?

- Very easy
- Relatively easy
- Relatively challenging
- Very challenging

In your opinion, is the design of the interface visually engaging?

- Yes
- No

What suggestions do you have, if any, for improving the design of the interface?

Please evaluate the impact of the interface:

| | No (0) | +1 | +2 | Yes, a lot (+3) |
|---|---|---|---|---|
| Did the display increase your awareness of the building's water consumption? | ☐ | ☐ | ☐ | ☐ |
| Did the display increase your awareness of water issues? | ☐ | ☐ | ☐ | ☐ |

| | | | | |
|---|---|---|---|---|
| Did the display increase your awareness of environmental issues? | ☐ | ☐ | ☐ | ☐ |
| Did the display give you enough guidance to reduce your water consumption at home and at 52 the Parade? | ☐ | ☐ | ☐ | ☐ |

In your opinion, can the display encourage you to save water?

- ○ Yes, in both the short and long term
- ○ Yes but only in the short term
- ○ Yes but only in the long term
- ○ No

In your opinion, the interface provides...

- ● ...Too little information about the building's water consumption
- ● ...Neither too much or too little information about the building's water consumption
- ● ...Too much information about the building's water consumption

Which feature did you check the most?

- ○ Overview of Water Consumption
- ○ Comparisons and Social Ranking
- ○ Financial Savings
- ○ Facts, Tips and Advice

Do you remember any of the tips and advice you read?

- Yes
- No

Please, write down one of the tips you remember:

In your opinion, what are the positive aspects of the interface?

In your opinion, what are the negative aspects of the interface?

What suggestions do you have, if any, for improving the content of the interface?

Would you be willing to use such a device at home?

- Yes
- No

Would you be willing to invest in such a device for your personal use?

- ○ Yes
- ○ No

Please assess the following statements:
Please don't select more than 1 answer(s) per row.

Please select at least 10 answer(s).

| | Strongly agree (+2) | +1 | 0 | -1 | Strongly disagree (-2) |
|---|---|---|---|---|---|
| Technology is my friend. | ☐ | ☐ | ☐ | ☐ | ☐ |
| I enjoy learning new computer programs/apps and hearing about new technologies. | ☐ | ☐ | ☐ | ☐ | ☐ |
| People expect me to know about technology and I don't want to let them down. | ☐ | ☐ | ☐ | ☐ | ☐ |
| If I am given an assignment that requires that I learn to use a new program or how to use a machine, I usually succeed. | ☐ | ☐ | ☐ | ☐ | ☐ |
| I relate well to technology and machines. | ☐ | ☐ | ☐ | ☐ | ☐ |

| | | | | | |
|---|---|---|---|---|---|
| I am comfortable learning new technology. | ☐ | ☐ | ☐ | ☐ | ☐ |
| I know how to deal with technological malfunctions or problems. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Solving a technological problem seems like a fun challenge. | ☐ | ☐ | ☐ | ☐ | ☐ |
| I find most technology easy to learn. | ☐ | ☐ | ☐ | ☐ | ☐ |
| I feel as up-to-date on technology As my peers. | ☐ | ☐ | ☐ | ☐ | ☐ |

If 'technophobia' is defined as feeling of discomfort about smartphones/apps or any technology, which of the following best describes you?

- ○ Highly technophobic (+3)
- ○ +2
- ○ +1
- ○ Not technophobic (0)

If you are happy to take part in a focus group regarding the use of this display (that will take place at 52 The Parade, over an hour), please enter your email address below:

**Thank you for your participation**

This questionnaire has been created in the context of a PhD research project, that is part of the EU FP7 WISDOM project.

As the smart meter connected to 52 the Parade has been removed a few months ago, the data provided reflected the building's water consumption over previous months and was randomised daily.

The WISDOM project aims at (a) increasing user awareness and modifying behaviours concerning the use of water, (b) achieving quantifiable reduction in water consumption and (c) reducing peak-period of water distribution loads by using Information and Communication Technologies (ICTs).

For more information about the WISDOM project, please visit: http://www.wisdom-project.eu/

# Appendix J – List of Statistical Tests

| Name of the test | Type of test | Description | Significance |
|---|---|---|---|
| **Binomial logistic regression** | Prediction | Predicts the probability that an observation falls into one of two categories of a dichotomous dependent variable based on one or more independent variables (continuous or categorical) [506]. | Regression model significant if $p < .05$ |
| **Chi-square test of association/ Chi-square test of independence** | Association | Measures the association between two nominal variables [506]. | Test statistically significant if $p < .05$<br>Strength of association: Cramer's V<br>0-0.2: weak association<br>0.2-0.5; Moderate association<br>0.5-1: strong association |
| **Chi-square test of homogeneity** | Group difference | Determines if a difference exists between the binomial proportions of three or more independent groups on a dichotomous dependent variable [506]. | Test statistically significant if $p < .05$<br>Strength of association: Phi:<br>0-0.2: weak association<br>0.2-0.5; Moderate association<br>0.5-1: strong association |
| **Cochran-Armitage test of trend** | Association | Determines whether there is a linear trend (i.e., a linear relationship/association) between an ordinal independent variable and a dichotomous dependent variable [506]. | Test statistically significant if $p < .05$ |
| **Confidence Interval** | | Refers to the amount of error that is allowed in the statistical data and analysis: 95% confidence intervals equates to declaring statistical significance at the $p < .05$ level. | Two-tailed confidence intervals means that one is 95% confident that the result lies between value a and value b. |

| | | | |
|---|---|---|---|
| **Fisher's exact test** | Association | Determines whether two dichotomous variables are independent [506]. | Test statistically significant if $p < .05$ |
| **Linear Regression** | Prediction | Assesses the linear relationship between two continuous variables to predict the value of a dependent variable based on the value of an independent variable [506]. | Regression model significant if $p < .05$ |
| **Mann-Whitney U test** | Group difference | Determines if there are differences between two groups on a continuous or ordinal dependent variable [506]. | Test statistically significant if $p < .05$ |
| **Odds ratios** | Association | Way to quantify how strongly the presence or absence of a variable is associated with the presence or absence of another variable in a given population [506]. | Strength of association:<br><br><1: an increase in one variable leads to an increase in the other variable.<br><br>>1: a decrease in one variable leads to a decrease in the other variable.<br><br>=1: no effect |
| **Pearson product-moment correlation** | Association | Determines the strength and direction of a linear relationship between two continuous variables [506]. | Test statistically significant if $p < .05$ |
| **Point-biserial correlation coefficient** | Association | Determines the strength of a linear relationship between one continuous variable and one nominal variable with two categories [506]. | Test statistically significant if $p < .05$ |

| | | | |
|---|---|---|---|
| **Somers' *d*** | Association | Measures the strength and direction of association that exists between an ordinal dependent variable and an ordinal independent variable [506]. | Test statistically significant if $p < .05$<br><br>Strength of association: Value of *d*<br><br>0-0.2: weak association<br><br>0.2-0.5; Moderate association<br><br>0.5-1: strong association |
| **Spearman's rank-order correlation** | Association | Measures the strength and direction of the association/relationship between two continuous or ordinal variables [506]. | Test statistically significant if $p < .05$ |

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