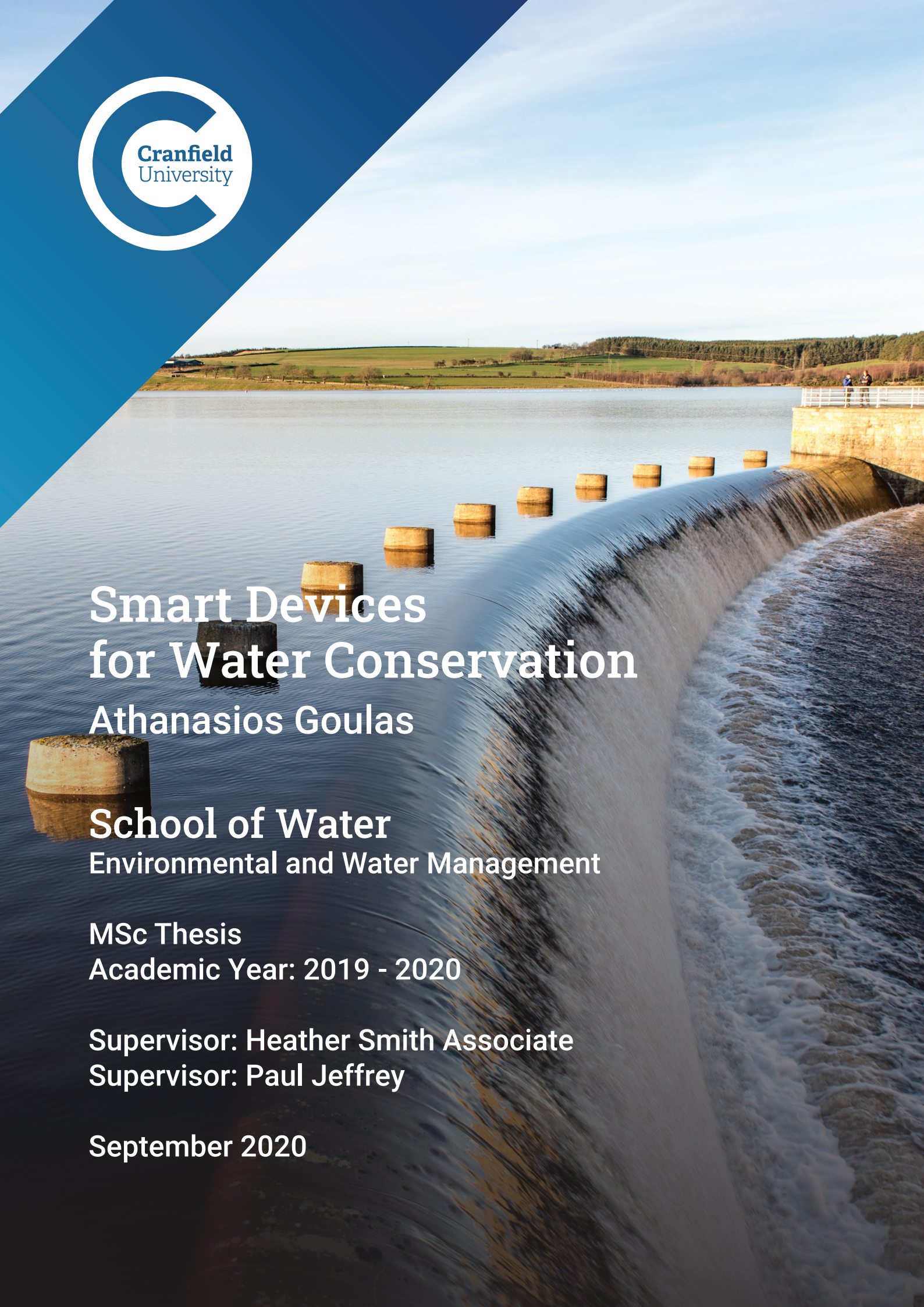

Smart Devices for Water Conservation

Athanasios Goulas

School of Water
Environmental and Water Management

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Supervisor: Heather Smith Associate
Supervisor: Paul Jeffrey

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Abstract

Many countries around the world are facing drought-related challenges due to increased water demand and population growth. Studies have shown that smart technology such as smart meters measuring domestic water consumption can play a significant role in reducing overall water demand. However, consumers' interests and needs can have an impact in their level of acceptance towards these devices. The aim of this paper is to explore attitudes and perceptions of domestic consumers towards Water Event Meters (WEMs) that use Internet of Things technology, can provide detailed feedback from every household appliance and will be used by British consumers in the near future. Furthermore, this research highlights the different barriers and challenges such as privacy, security and cost that dissuade consumers to accept them. Using a combination of the existing literature review and an online survey that implemented in the UK (N=558), this paper responds to the question of how likely British citizens are, to accept the installation of a Water Event Meter. Results have shown that the majority of the participants would accept one advanced smart water meter while there is a great proportion of respondents who are hesitant but they might accept it in the future. Responses were affected by sociodemographic characteristics such as age and education level. However, as this is an emerging technology that has not been available for public use yet, further research is needed so stronger evidences will be provided in the future.

Keywords:
Advanced smart devices, Water Event Meters, domestic water consumption, public perceptions, consumer acceptance, online survey

Acknowledgements

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To conclude, I would like to thank my family for supporting me both financially and mentally during the implementation of my master's degree.

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List of Abbreviations

GSM: Global System for Mobile Communications

GPRS: General Packet Radio Service

CDMA: Code-division Multiple Access

AMR: Automatic Meter Reading

AMI: Advanced Metering Infrastructure

IoT: Internet of Things

WEM: Water Event Meter

1 Introduction

1.1 The importance of more effective monitoring of water consumption in the UK

It has been estimated that water will become scarce in many countries around the world due to increased water demand because of population growth and with the impact of climate change remaining uncertain in the future. Thus, Internet of Things (IoT) smart water management solutions can play a significant role in order to avoid a future water crisis. In the case of the UK, its population is expected to rise by 4.5% (Nash, 2019) which will result in an approximately 15% increase in the water withdrawn from the environment(Lawson et al., 2018). Nowadays, daily per capita water consumption in the UK is around 140 litres and approximately 55% of water put into the supply system of England and Wales, is used for domestic activities(Lawson et al., 2018). Domestic water usage accounts for 14% of the total water consumption and according to a research (see Water Resources Group, 2009) this number may grow in specific basins, of emerging markets. Also, considering future projections, that fresh water will face a 40% deficiency globally by 2030 due to economic (industrial and agricultural water withdrawals will be increased) and social development (Water Resources Group, 2009) , it is essential that more effective measurement of water consumption should be implemented. Moreover, leakage levels pose a threat in maintaining the balance between water supply and demand. Particularly in the UK, according to recent reports, around 3,170 million litres of water are lost through leakage and presents a challenge for both water companies and the property owner (Price Waterhouse, 2019).

An important factor that affects domestic water consumption, lies in the fact of the installation of water meters in households. According to Lawson et al., 2018, the average consumption of a metered household in England and Wales is 266 l/property/day, whereas in an unmetered household is 379 l/property/day (Appendix B). Metering houses, which developed rapidly after 1999 in the UK(Lawson et al., 2018), provide positive effects to consumers from a financial perspective as they help them to lower their water bills, reduce average water consumption to more than 14% and detect easier potential leaks (Ornaghi and Tonin, 2015). Installing water meters is of high importance because not only they provide water companies and insurances with detailed feedback concerning real- time water consumption, for further processing but they help customers to manage and decrease their water consumption. This study is focused on the latter which can be implemented more effectively by advanced smart meters compared to conventional or conventional smart water meters (Table 1).

1.2 Background and classification of smart water metering devices

Decrease in domestic water consumption can be achieved through economic incentives such as (e.g. tax incentives), technological development (e.g. advanced in-home devices that measure water usage) or changes in regulations and policies (Koop, et al., 2019). Smart metering is an emerging technology that was first introduced in 1970s yet it grew rapidly during the past decade (Darby, 2010). Nowadays, Water Event Meters (this term is not a wide industry term, it is the term that the company Creative EC uses for advanced smart devices) are able to provide real-time and detailed data (like water pressure, temperature, water flow) as well as they measure the exact amount of water consumption for every household activity (e.g. bathing, dishwashing, etc.). Technological initiatives such as Water Event Meters that will be installed in residences in the coming years , can provide accurate and automatic monitoring as they collect and analyse higher resolution water consumption data than traditional devices(Liu, et al., 2015). In addition, they provide the consumer with detailed feedback in an effort to raise awareness about excessive domestic water demand. Furthermore, by using this type of metering, consumers can be informed rapidly and remotely in a case of an unwanted event such as leakage (e.g. with an acoustic leak detection system). An example of a WEM that uses Internet of Things technology and an on-site sensor device to measure daily water consumption from every household appliance is Waterfall device (Figure 1) (EC, 2019).

Table 1: Classification of smart water devices

Conventional water meter	Conventional water meters are not able to provide real-time water consumption data, as they only count liters of water that flow through the system without recording the time of day or the type of activity that is responsible for the water consumption (Willis et al., 2010).
Conventional smart water meters (SWMs)	Conventional smart water meters (SWM) are digital meters that monitor how much water a household uses and whose readings are read remotely by the water company. With a smart meter, consumer no longer has to report meter readings himself. Also, no meter reader has to stop by. SWM may be classified as Automated Meter Reading (AMR) or Advanced Metering Infrastructure (AMI) (Boyle et al., 2013). AMR is a form of remote meter reading which transfers automatically water consumption data through public (GSM, GPRS, CDMA) or private radio network, to servers of companies that process the data and provide the customer with accurate feedback (Readdy, 2006). AMI has the same function but provides higher data density and is more technologically advanced than AMR (Boyle et al., 2013) (Martins et al., 2019).
Water Event Meters (WEMs) – advanced smart water meters	These are water meters that use Internet of Things (emerging network superstructure) technology to monitor and analyse real-time water consumption. They can provide detailed feedback to the consumer on water usage from every household appliance, which can be read remotely through online apps. They have no moving parts and they are designed to have a simple installation. Combining Internet of Things, cloud and machine learning technologies, they not only supply but also predict water usage data in real time. Some provide advanced leakage detection and warning systems (Waterfall device). The connection of the WEM with the different domestic devices is assisted by sensors that have been installed on water supply pipes at different spots in the house (kitchen tap, dishwasher, toilet, etc.) (Yang et al., 2017).

Figure 1: Waterfall device. An example of a Water Event Meter). (Source: Creative EC)

1.3 Consumer acceptance of advanced smart meters

Despite the benefits of advanced metering, it is of high importance consumers accept these devices in their houses in order to take advantage of their full potential. For that reason, water utilities in the UK, in order to explore customers' preferences have developed business plans that will strengthen their relationship with the consumer and will improve their service levels (Lanz et al., 2016). Water companies such as Southern, South East, Thames and Affinity Water have created compulsory and advanced meter programmes, in order to increase consumers acceptance towards conventional smart water meters (Lawson et al., 2018). Their goal is to have installed conventional smart water meters in more than 75% of their customers' properties by 2045 (Appendix B.2).

Based on this, this research explores attitudes and perspectives of British citizens towards Water Event Meters that provide water consumption feedback and examines potential barriers and challenges (e.g. privacy, security, installation cost, reliability) associated with this technology. In particular, this paper focuses on the following research question: how likely British citizens with different demographic characteristics (e.g. age, income, education level, household composition) are, to accept the installation of a Water Event Meter in their residence? As the literature states, advanced and smart metering offer a number of opportunities and with the detailed feedback they provide, they motivate consumers to use water more efficiently. However, the importance of consumers' acceptance towards these devices is highlighted and the most important challenges that affect their willingness to accept them are mentioned. The sections following literature review, illustrate the methodological background of the study and describe the results of the research. In the end, the importance of the given results is evaluated and discussed before reaching a conclusion.

2 Literature Review

This literature review searched for papers describing attitudes and behaviours of consumers towards not only conventional smart in-home water meters (SWMs) but also energy smart devices that have been installed in residences. Although, much of this research has focused on multiple benefits provided by conventional smart devices, that may encourage consumers on reducing water and energy consumption (Monks et al., 2019), a number of papers illustrate barriers and challenges of conventional smart meters that affect citizens' acceptance towards these devices (Balta-Ozkan et al., 2013) (Horne et al., 2015). The purpose was to identify people's perspectives that are associated with the use of WEMs and explore potential barriers that dissuade them from installing this type of meters. However, there is a research gap associated with Water Event Meters as they are an emerging technology that has not been available for public use yet.

2.1 The role of smart devices in changing consumers' attitudes

In the following decades, water resources are expected to become scarce as a result of population growth and future climate change. Hence, the need to motivate citizens to consume water sustainably becomes urgent (Liu, Giurco and Mukheibir, 2015). Despite studies have shown, (Vanham et al., 2018, Koop and van Leeuwen, 2017) that the greatest risk posed to freshwater resources is created by the increased water demand for food production, households can play a significant role in decreasing overall water loss (Koop, et al., 2019). Installing conventional smart water devices, enables the collection and analysis of more detailed water consumption feedback which can be read remotely through online apps compared to conventional metering (Liu, Giurco and Mukheibir, 2015), acting in that way as a signal to customers who will then be aware of their daily water consumption. Accordingly, using conventional smart devices can raise consumers' awareness towards their water usage, a fact that can play a significant role in changing people's behaviour and water consumption patterns ensuring in that way that water will be used sustainably, which can be very important especially in situations of water- shortage.

Today, a lot of water companies in Europe are trying to strengthen the connection with their customers and be more attentive to their expectations and attitudes towards water consumption (Brouwer et al., 2019). The processing of the detailed water consumption feedback provided by conventional smart water meters, could help water utilities identify if they are significant behavioural changes in their consumers' water usage. Furthermore, studies have shown that different demographic characteristics of consumers may have an impact in their water usage. According to a survey of almost 27,000 Spanish households, Mondéjar et al., (2011) identified that citizens with higher educational level and income tend to consume more water as a result of their comfortable lifestyle, while individual water consumption declines when families consist of more members (Willis et al., 2013). As a consequence, the role of smart meters that provide detailed feedback can be of significant importance. In that case, consumers will be aware of their daily water consumption, a fact that may affect their water use behaviour and may motivate them to adopt a more sustainable lifestyle regardless their different characteristics (e.g. social status, household composition). Similarly, Beal, et al., (2013) observed that received feedback concerning the water usage of householders compared to other consumers, could minimize the gap between their perceptions of their water usage and their actual consumption.

2.2 Opportunities of conventional smart domestic devices

Householders may not be completely aware of their daily water consumption resulting in excessive water loss during their daily activities. Considering the above, studies have shown that conventional smart water metering, as opposed to conventional metering, provides detailed feedback concerning daily water consumption and may encourage consumers to save water and raise awareness of sustainable water use. (Liu, Giurco and Mukheibir, 2015).

First of all, one of the most important benefits conventional smart meters provide to consumers is that they may benefit them from a financial perspective. For example, a conventional smart water device that allows citizens to monitor both their daily water and energy consumption directly or even receive signals when they exceed the average consumption level, will help them control and reduce their monthly bills more easily (Montginoul and Vestier, 2018). Similarly, Monks et al., (2019) stated that a key benefit provided by conventional smart devices and can be implemented more effectively by Water Event Meters (e.g. Waterfall device), is the automated alerting to potential leaks which can be of high importance, from a financial perspective, as the

consumer can act immediately and reduce the time of water leakage.

Furthermore, smart-meter based feedback on energy and water consumption provided by conventional smart devices can lead to energy and water savings. Henn et al (2019) took a similar view, that received data from conventional smart devices can motivate consumers to reduce their daily consumption, increasing in that way their level of environmental attitude. However, Karlin, et al (2015) claimed that a person's concern tends to raise only if the consumer identifies a significantly higher than expected consumption level. In contrast with the previous research, March et al., (2017) presented the report of the Spanish water company Aguas de Valencia, which illustrated that smart metering schemes can save more than 4 million cubic metres per year, decreasing in that way carbon dioxide emissions by 600 tons. These numbers can be explained, owing to the fact that lower water consumption reduces the amount of energy used for pumping throughout production and distribution processes. This reduction contributes to lower carbon dioxide levels generated from water supply systems, a fact that enhances future climate resilience. However, decreasing water consumption associated with conventional smart-meter devices, is based on the frequency someone monitors the provided data. Considering the above, it is perceived that people who are environmentally-conscious and interact on a daily basis with smart meters, are expected to adopt a more sustainable attitude towards their daily consumption compared to others. On the other hand, WEMs can provide even more opportunities, as they are more advanced than conventional smart devices. The basic difference lies in the capability of the former to forward real-time detailed feedback to water companies through IoT and to consumers via online apps from every household appliance. Also, Water Event Meters can be shut down remotely by consumers when they identify warnings of water escapes which in the case of conventional metering is impossible.

2.2.1 Challenges and barriers that affect consumers' acceptance towards conventional smart devices and Water Event Meters.

Water Event Meters are an emerging technological innovation that may provide various opportunities to householders. Nonetheless, many of them are not aware of their potential which in conjunction with their lack of knowledge towards smart devices, pose barriers to advanced smart meter acceptance. These challenges and the literature exploring consumers' attitude towards advanced and conventional smart domestic devices are introduced and discussed here.

Firstly, numerous studies that examine public perceptions towards conventional smart meters, have shown that privacy and security threats may affect the demand for new smart technologies(Horne et al., 2015)(Georgiev and Schlögl, 2018). Chawla, et al (2020) presented the results of a case study in Turkey, which illustrates citizens willingness to accept smart domestic devices if they do not interfere with their privacy. Specifically, over half of the population that participated in the survey feared that their privacy may be violated. Similarly, Balta-Ozkan et al., (2013) argued that sharing consumer information may be fraught with dangers as the data may fall into the hands of malicious parties. In this context, consumers who lack confidence in the network system and are concerned over third parties that may know their daily routines and activities through the detailed feedback provided by advanced smart devices, would prefer more conventional metering techniques rather than digital smart meters. As far as energy smart devices are concerned, there is a number of people, that despite data privacy concerns, are willing to share their consumption data, if it will assure them lower electric bills (Chawla, Kowalska-Pyzalska and Oralhan, 2020).

Secondly, another challenge that raise consumers' concern towards smart devices are high installation costs. According to Balta-Ozkan et al., (2013) citizens expect to see significant cost savings in the long-term, in order to offset installation costs. According to Spence et al., (2015), who presented the results of a survey of over 2400 UK citizens, people who are concerned about the cost of conventional smart devices are unlikely to accept them and consent to share their consumption data, while consumers who are concerned with protecting and preserving the environment are expected to support this technology. On the other hand, consumers are very interested in installing a conventional smart meter in their houses and are willing to accept it, especially if they do not need to pay for implementation(Chawla, Kowalska-Pyzalska and Oralhan, 2020).

Furthermore, consumers seem to be unaware or confused about conventional smart meters and their implementation. Likewise, the results of a survey that took place in the UK illustrated that half of the respondents had heard of smart meter devices but they were confused about their functionality and benefits (Buchanan et al., 2016). Based on numerous interview results presented by Krishnamurti et al., (2012), none of the 22 interviewees that participated in the survey, were able to describe accurately the aim and function of smart devices. Although most of interviewees were positive towards smart devices, lack of knowledge created misconceptions that were identified as interviewees had different expectations from the use of conventional smart meters and had

not realized the real potential and financial benefits that these devices could provide them. Taking this under consideration, it is made clear that people who have been properly informed about details of using smart devices and their function, are likely to accept them in the future and make the most of them. Also, there is a slight concern, how will the more vulnerable members of society, such as elderly people, use these devices as they may be not experienced with smart metering compared to younger population (Buchanan et al., 2016).

Moreover, consumers are concerned about reliability of smart water and energy domestic devices. For example, most of them are worried about the potential consequences should the device accidentally switch of or presents inaccurate consumption data (Balta-Ozkan et al., 2013). In the case of conventional smart and advanced devices, consumers' lack of trust in water or energy companies generates suspicious questions as citizens are keen to know which parties are financially benefited from these devices and how they will profit from smart metering in the future (Buchanan et al., 2016).

In the case of devices that use IoT technology (such as Water Event Meters), people are hesitant to accept them as they feel that this type of network would be difficult to use (Gao and Bai, 2014). In the same context, lack of trust and information by users towards advanced metering is another challenge that companies have to overcome. Studies have shown that consumers are concerned when they have to use devices that provide more IT interaction as they feel they do not have the full control of the device (Gao and Bai, 2014).

In conclusion, more research should be implemented in the case of home automation and whether or not satisfies consumers' needs and expectations. Thus, a gap has been identified between what WEMs provide and what consumers actually request. Moreover, Katz et al., (2016) claimed that in recent past, the knowledge about how consumers' attitudes can change concerning their daily domestic consumption is not sufficient. Furthermore, there is a lack of literature reports on Water Event Meters and consumers' perceptions towards these devices. Based on the existing literature a number of consumers consider conventional smart meters as a threat to their privacy as they are afraid their data will be monitored by third parties while others are dissuaded by the high installation costs of these devices. However, results of surveys show that most citizens agree that the use of conventional smart meters can be beneficial for them, especially from a financial perspective (Krishnamurti et al., 2012). These results are of high importance because technological development (i.e. advanced smart metering-WEMs) has the potential to provide numerous benefits but only in the case it is socially accepted by citizens (Georgiev and Schlögl, 2018).

2.3 Aim and Objectives

The aim of the project "Smart devices for water conservation" is to explore attitudes and perceptions towards advanced smart domestic devices that provide information on household water use and will be used by British citizens in the future. Furthermore, during the implementation of this project challenges and barriers associated with the installation of these devices, will be explored and analysed in order to identify consumer's opinion before these devices become available to the general public. The overall objectives are to:

1. Understand current state of the art thinking on perceptions and attitudes towards the use of smart in-home devices, supported by existing literature.
2. Understand UK citizens' acceptance towards Water Event Meters that have not been available to public yet and explore perceptions of UK general public with different characteristics (e.g. social status, income, educational level) for this type of metering.
3. Identify barriers and challenges of WEMs that dissuade British people to accept them.
4. Identify the connection between the overall attitude of British consumers towards water resources and their acceptance towards WEMs.
5. Identify recommendations to support further acceptance of WEMs.

3 Methodology

This study used a structure survey to examine perceptions and general acceptance level of consumers towards Water Event Meters for domestic use and identify potential barriers and challenges that discourage them from accepting these devices. The study area of the survey was the UK general public with people at different life stages with different sociodemographic characteristics split into subgroups for the implementation of the statistical analysis of the results. Before the implementation of this project and data collection, an ethical approval was obtained.

3.1 Survey description

The research contains quantitative data collected from a questionnaire which was designed by using the web-based software "Qualtrics'. This type of research was considered the best data collection method, as it is a less-time consuming and time saving method while it is an accurate and effective technique of obtaining a broad range of data from a large number of respondents. The online survey was undertaken in July 2020 and its objective was to identify the insights of UK citizens with different attributes (e.g. age, educational level, household composition) for Water Event Meters used for monitoring water domestic consumption. In the Appendix A, the full questionnaire can be found.

To begin with, before the distribution of the survey, a number of pre-tests were undertaken by volunteers (N=10) in order to check for potential problems and ensure that the survey follows a logical order and is user-friendly. Afterwards, volunteers provided feedback and the survey was published to the public.

Firstly, participants were asked to agree on a consent form and complete a number of demographic questions such as: age, gender, highest educational level, ethnicity, location of residence and family composition. Following this, consumers were asked if they have a water meter (either conventional or conventional smart) in their residence. Moreover, the survey was focused on WEMs where a number of multiple choice questions were used in order to explore their perspectives on advanced smart water metering and identify barriers that affect their acceptance such as: privacy, security, reliability. A number of individual questions were recorded using a 3-point scale: 1= Agree, 2= Neutral, 3= Disagree. Taking into account the aforesaid, in this survey, participants were asked questions not only for Water Event Meters that will be available for public use in the future but also for conventional and conventional smart water meters (SWMs). The reason behind this choice lies in the fact, that British citizens have a clearer view of this type of metering as many of them have already installed and use these devices in their homes.

3.2 Four different perspectives

After the demographic questions, participants were asked to choose between four different drinking water perspectives in order to identify whether their approach towards drinking water has a strong effect on their decision to accept a Water Event Meter. The four different perspectives were based on a research, which was implemented by Brouwer et al., (2019) for the population of Netherlands and aimed to assist water utilities to discover citizens' concerns and insights, so the former will meet their needs and wants. The first perspective focused on consumers' responsibility to consume water wisely and highlighted the role of water utilities in water distribution and production. Secondly, the following perspective described the concern about the quality of water and emphasized the value of human health. According to the third perspective, water is an essential human right which should be accessible to every person on the planet and not only for households who pay for their water consumption. Lastly, participants who chose the fourth perspective are not concerned about the future of water resources and trust their water utilities to ensure high quality of drinking water (Appendix A.1.2).

3.2.1 Dependent and independent variables

First of all, Likert-type questions were used to quantify the dependent variable which in the case of this study was the general acceptance of UK citizens towards Water Event Meters. The different demographic characteristics of the participants and the four different perspectives were the independent variables of the research design. Furthermore, the possibility of British consumers to have or not a water meter installed in their residence as well as the number of smart devices respondents already have, were considered as independent variables that may influence their acceptance towards a WEM.

3.3 Analysis

All data were analysed using the IBM SPSS Statistics software platform. In the Appendix C, cross-tabulation tables that describe demographic characteristics with the dependent variable can be found. Cross-tabulation of age with the group of people who answered "YES"(Group 1), "NO" (Group 0) and "MAYBE" (Group=2) in the question about their willingness to accept a WEM in their homes shown in Appendix C.6. One-way ANOVA was used in order to explore the acceptance level towards the use of WEMs of the different age groups. The age group used for the analysis were: 18-24, 25-34, 35-49, 50-64 and over 65. The first hypothesis (H1) was that demographic variables will have an effect on the acceptance of a Water Event Meter. The second hypothesis (H2) was that having already installed a water meter (either conventional or conventional smart water meter) that measures water consumption would have an effect in the willingness to accept the installation of a Water Event Meter. A post-hoc test was run, to determine if the acceptance of British consumers towards WEMs changed considerably with the number of smart devices consumers already have (H3). Considering the four different perspectives, the fourth hypothesis (H4) was that each perspective influences the acceptance of consumers on Water Event Meters.

4 Results

4.1 Demographic characteristics of participants

A total of 558 participants were included in the survey and the analysis. Figure 2 shows that most of the participants belong to the age group of 35 to 49 years. In addition, the number of females that participated was approximately 4% higher than females as it is illustrated in Figure 5. Also, participants were asked if they live in a house with a person who has a disability, with most of them replying negatively (Figure 4). Moreover, a minor difference was observed in the percentage that indicated the family composition of the respondents (Figure 3).

Figure 2: Pie chart that illustrates the percentage of the different age groups of respondents that participated in the survey.

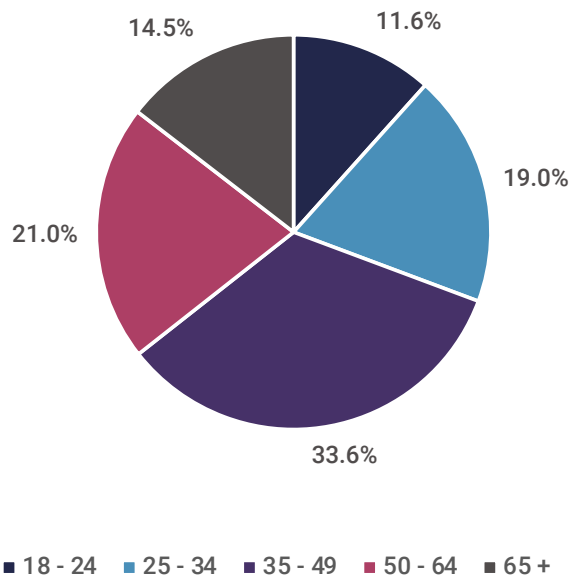


Figure 3: Pie chart that illustrates the percentage of different households based on the family composition.

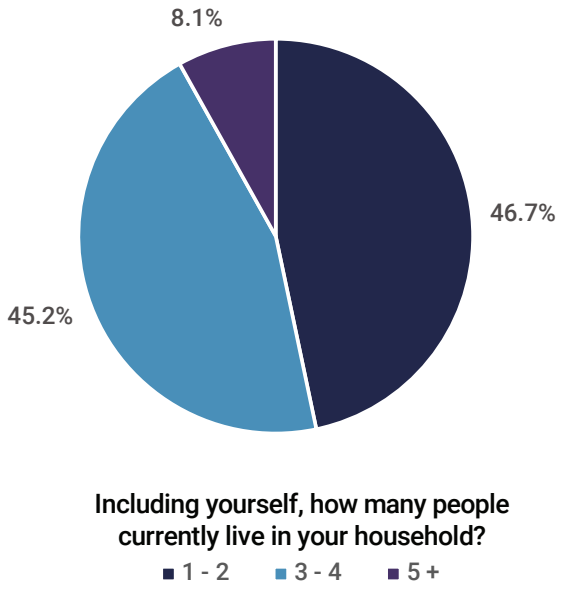


Figure 4: Pie chart that illustrates the percentage of households that include or not a disable person.

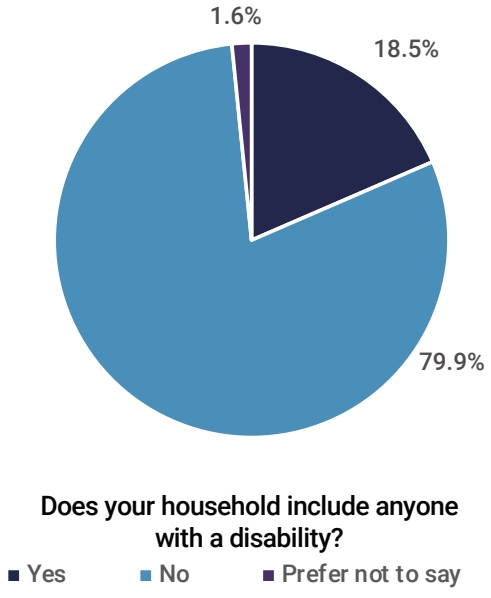
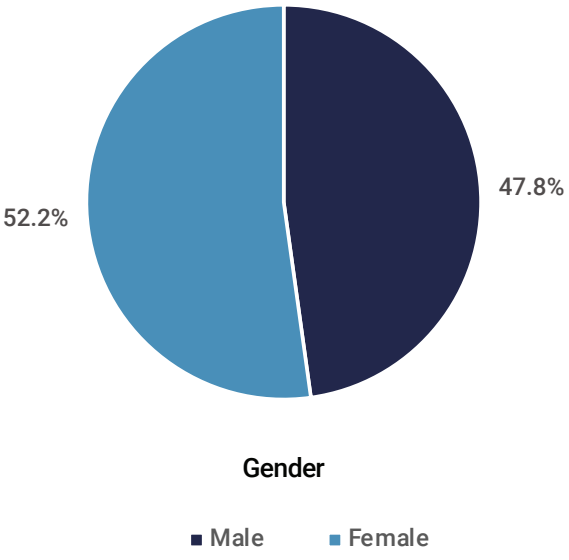


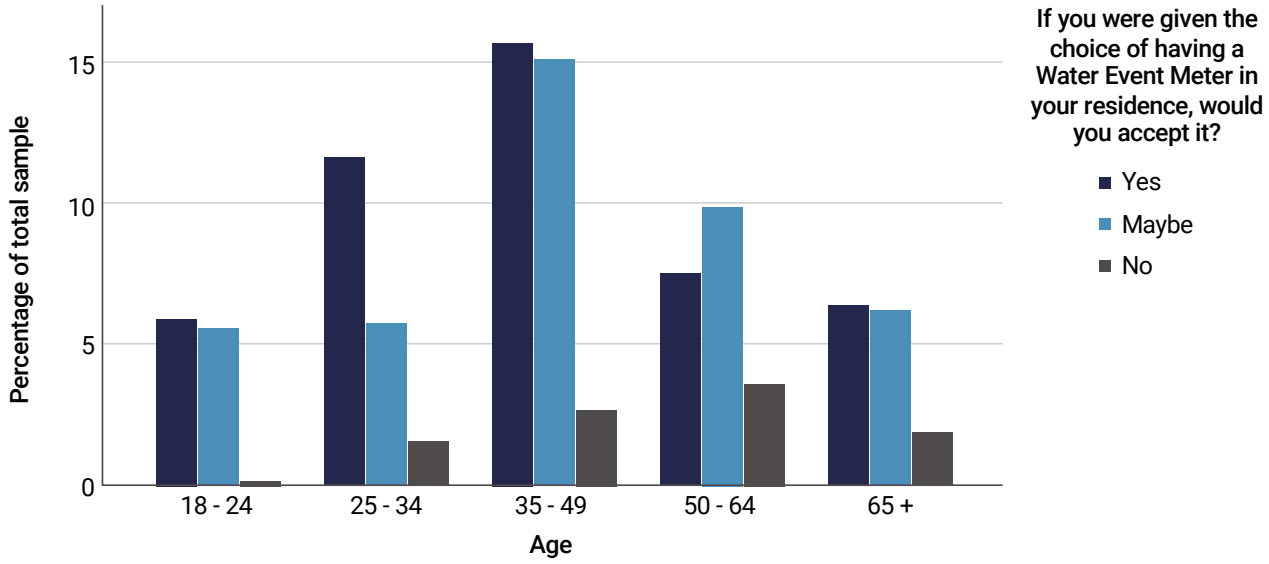
Figure 5: Pie chart that illustrates the percentage of males and females that participated in the survey.



4.2 General acceptance of British consumers towards WEMs

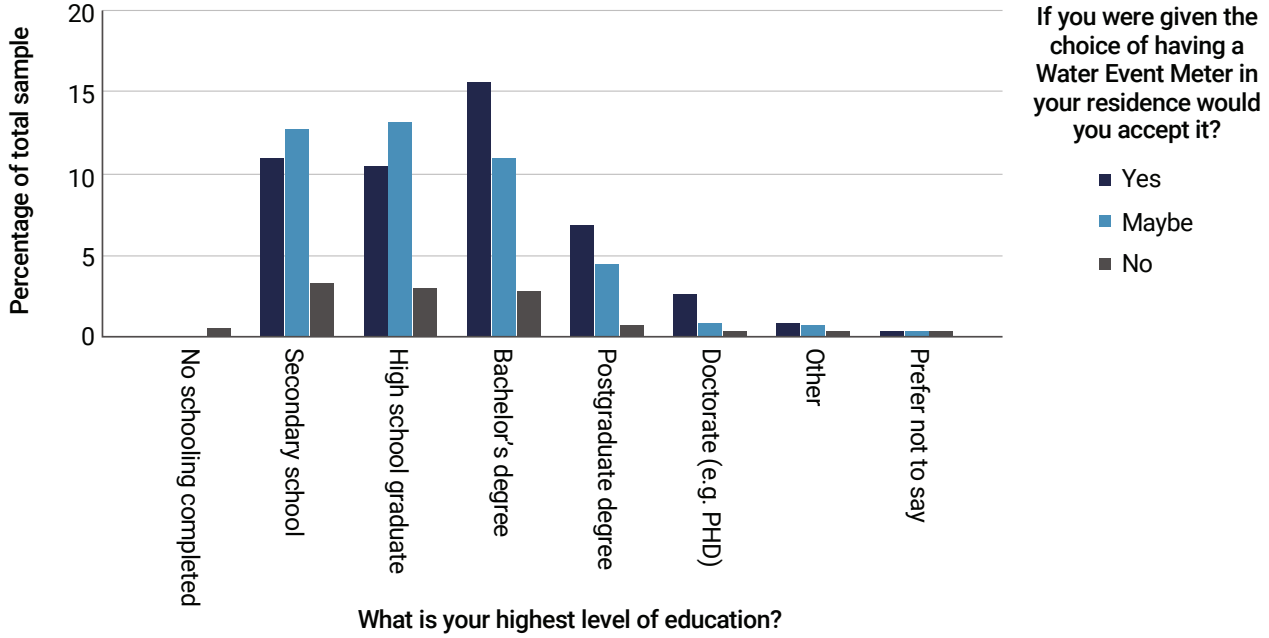
Overall, nearly half of respondents (48%) said they would accept a WEM, 43% said "Maybe", and 9% said no (Appenxix D). ANOVA showed that from the demographic characteristics (age, gender, family composition, disability, water bills, educational level) of respondents, only age ($p < 0.001$) and educational level ($p=0.001$) had a statistically significant difference with their acceptance towards WEMs. As it is depicted in Figure 6, the greatest percentage of people that would accept these new devices were consumers between 35-49 years old (15,8%) while middle aged people between 50-64 years are hesitant about WEMs but they do not reject it (9.9%).

Figure 6: Clustered bar that illustrates the different ages of British consumers with their acceptance towards WEMs



As far as the level of education is concerned (Figure 7) , 15.8% of British consumers who are positive about the installation of a Water Event Meter in their residence have a bachelor degree as their highest educational level whereas the highest percentage of high school graduates is uncertain although they could accept it in the future (13.2%). It is of high importance to mention, that there is a statistically significant difference in the willingness to accept a WEM between consumers who have not completed the school and those who have a bachelor degree ($p=0.41$), postgraduate degree ($p=0.24$) and doctorate ($p=013$).

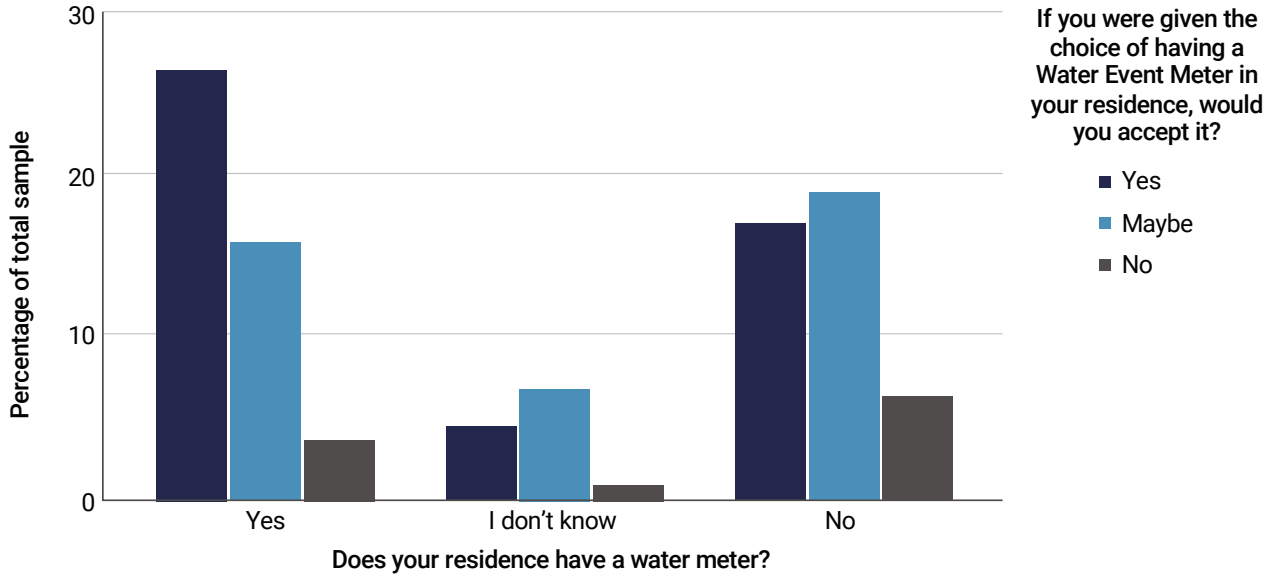
Figure 7: Clustered bar that illustrates the correlation between the highest educational level of participants with their willingness to accept a WEM



4.3 Willingness to accept a WEM based on having a water meter and other smart devices

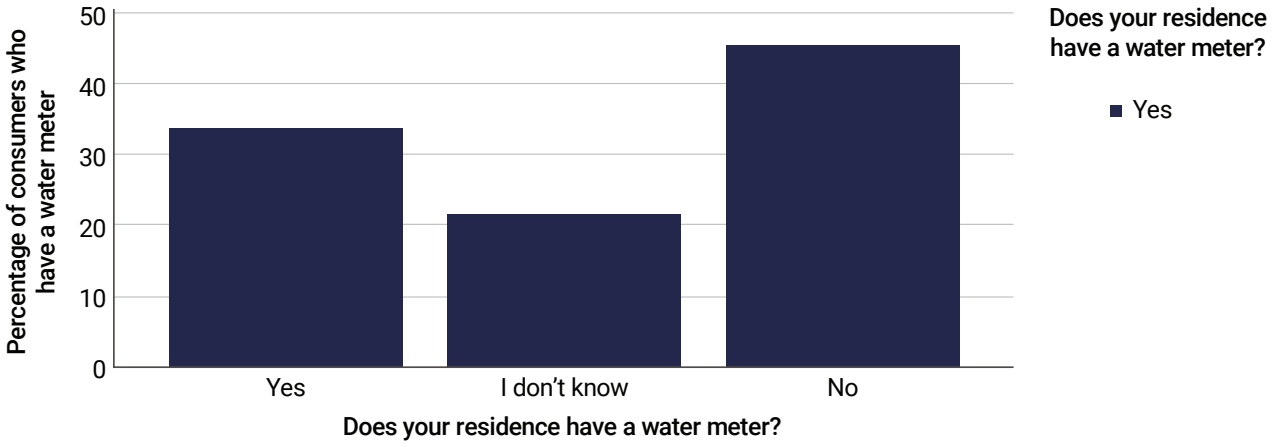
Figure 8 represents the percentage of domestic consumers that have or not a conventional or a conventional smart water meter(SWMs) in their residence with their willingness to accept a WEM. ANOVA showed that there is a statistically significant difference ($p<0.01$) between consumers who have and those who have not a water meter in their residence and their level of acceptance towards WEMs, with most of consumers who already have a water meter being willing to accept these devices. As it is depicted in the graph, out of the 558 domestic consumers that participated in the survey,140 (26.5%) already have a water meter installed at home and are positive towards the installation of a WEM in the future. On the other hand, in the case of the consumers who do not have a water meter, there is a slight difference of approximately 1.7% between those who have accepted a WEM (17.1%) and those whose may accept one (18.8%).

Figure 8: Clustered bar that illustrates the percentage of participants that have or not a water meter (Either conventional or SWM) in their residence with their willingness to accept a WEM.



Following the results of the previous questions, consumers who replied positively in the question "Does your residence have a water meter", were asked if the existing water meter is smart or not. From the total number of 241 consumers, only 81 replied that their water meter is smart while 44.8% of the participants (N=108) answered negatively (Figure 9).

Figure 9: Bar graph that illustrates the percentage of domestic consumers who have a water meter in their residence with the percentage of residences that have installed a smart meter.



A hypothesis that was tested was whether having more smart devices such as: smart phones, fitness trackers, smart speakers and others, would increase the willingness of consumers to accept a WEM. More specifically, based on the results displayed in the following table (Table 2), the percentage of participants who have 3 smart devices and are willing to accept the installation of a WEM in their residences rises up to 64.5%, which is approximately 13% higher compared to consumers who have only one smart device. The results of a post-hoc test showed, that there is a statistically significant difference, between those who have one smart device and those who have 3 ($p<0.001$). Finally, all of the participants who have 6 smart devices are positive towards WEMs but the reliability of this result is questionable because the sample is very low as only 5 people belong in that group.

Table 2 : Cross-tabulation of the number of smart devices domestic consumers have with three different groups of British consumers: Group 0 corresponds to consumers who do not accept a WEM in their homes, Group 1 to consumers who accept a WEM and "Group 2" to those who answered "Maybe".

Number of smart devices	WEM (Percentage)			Total
	Group 0 (No)	Group 1 (Yes)	Group 2 (Maybe)	
1	9.4%	51.5%	39.1%	100%
2	7.2%	57%	35.7%	100%
3	7.2%	64.5%	28.3%	100%
4	9.1%	59.1%	31.8%	100%
5	16.7%	55.6%	27.8%	100%
6	0	100%	0	100%

4.4 Preferences towards the acceptance of WEMs

Keeping in mind the aforesaid, a number of studies has shown that installation costs and privacy violation of conventional smart water meters are factors that affect the acceptance of consumers towards these meters. Table 3 displays a number of behavioural questions and the mean values with the standard deviations of the responses (1= More likely to accept, 2= No change, 3= Less likely to accept) in order to explore what may motivate consumers to accept this type of metering. It can be seen from the mean value that is closer to 1, that most of the participants are willing to accept a WEM, if they did not have to pay for the installation costs rather than purchase it from water companies or third parties. Also, domestic consumers are very likely to accept this device, if it would help them reduce their water and insurance bills. Likewise, it is of high importance to mention, that respondents would like to have the total control of who will have access to the feedback provided by the device, so they will not have to worry that their data will fall into the hands of malicious parties.

Table 3: Mean values of variables A1-A6.

Variables	Mean	Standard Deviation
(A1) If it was provided free of charge by my water company	1.28	0.494
(A2) If it helped me reduce my water bills	1.30	0.536
(A3) If it reduced my insurance bills	1.37	0.559
(A4) If I could control who had access to the data	1.52	0.592
(A5) If I could purchase it or rent it from my water company	2.22	0.720
(A6) If I could purchase it or rent it from a third party	2.33	0.712

Further to the previous behavioral questions, Table 4 displays five more questions and their mean values, in order to test how reliable consumers believe the data provided by a WEM is (A9) and further understand their attitudes towards the challenges such as high installation costs and privacy protection. The following responses were ranked using a three-point Likert scale, where 1= Agree, 3= Disagree and 2= Neutral. As it is depicted in the table most of the participants are likely to agree with the fact that the installation of a WEM may be costly and that the data provided by the device is reliable. In addition, consumers feel more secure in sharing their data with their water companies(A9) than with third parties (A11).

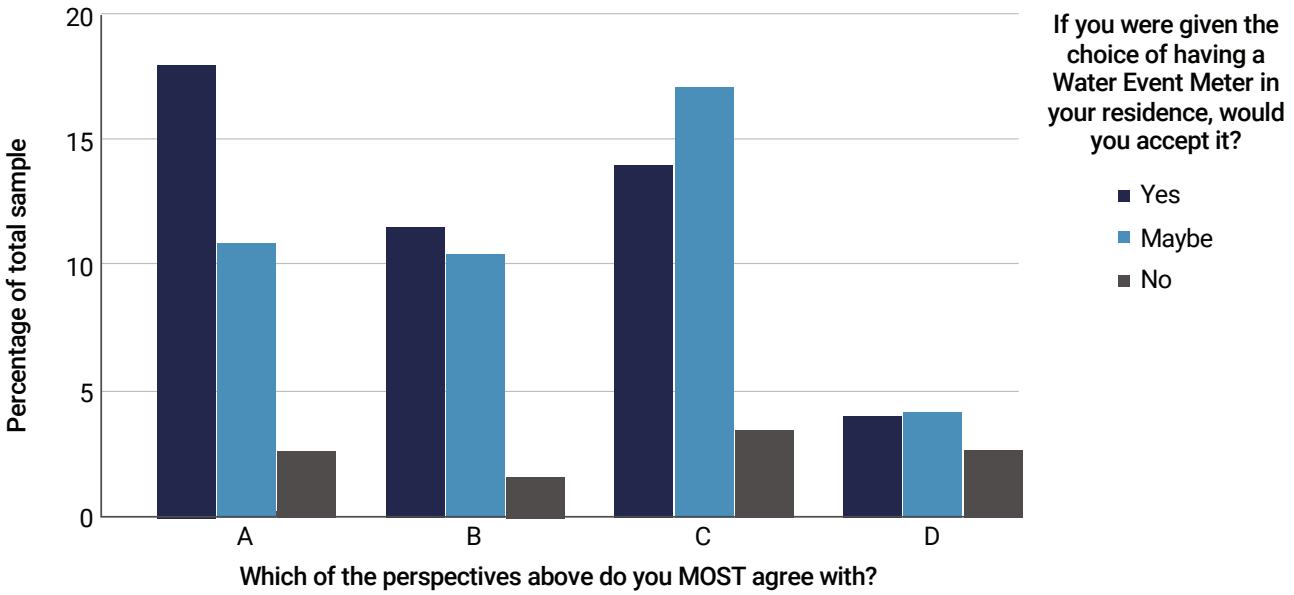
Table 4: Mean values of variables A7-A11.

Variables	Mean	Standard Deviation
(A7) It's ok for water companies to have access to the data from WEMs	1.61	0.660
(A8) WEMs would probably cost a lot	1.62	0.624
(A9) I believe that the data from WEMs if likely to be correct	1.66	0.592
(A10) I see no benefits from WEMs	2.23	0.734

4.5 The impact of the four perspectives on the willingness to accept a WEM

The percentage associated with the different drinking water perspectives across the three groups of domestic consumers are reported in Figure 10. It can be seen that, the highest percentage of participants who are willing to accept a WEM in their residence, are individuals who are aware of environmental challenges and are ready to adopt a more environmental friendly behaviour (perspective A, 17.9%). On the other hand, the lowest proportion of people who are willing to accept a WEM, is observed in the fourth group (perspective D, 3.9%) who consider the importance of drinking water companies in being responsible for providing adequate and good quality of water and believe that any extra products that ensure sustainable use of water (e.g. smart devices) are unnecessary. In order to test the hypothesis, that different water drinking perspectives had an effect on the level of acceptance of British consumers, a one-way ANOVA was performed. The results of the ANOVA test showed that there is a significant statistically difference between the four different drinking water perspectives and the willingness of domestic consumers to accept WEMs ($p=0.02$). Thus, the null hypothesis of no differences between the means of perspectives if rejected. To evaluate the nature of differences between the four means, a post-hoc test was implemented and illustrated a statistically significant difference in the willingness of consumers to accept a WEM, between perspectives A and D ($p=0.03$).

Figure 10 : Clustered bar that illustrates the correlation of the four different drinking water perspectives with the acceptance of domestic consumers towards WEMs.



5 Discussion

Consumer acceptance of Water Event Meters is essential in order to understand their benefits and realise their full potential. In this study, the willingness of domestic British consumers to accept a WEM was investigated by organising a structure survey. The analysis supports the theory, that approximately half of the domestic consumers that participated in that survey are willing to accept a WEM in their homes. The results indicated that the majority of participants are positive towards the installation of WEMs, reaching a percentage of 47.5%. Furthermore, approximately 42% of the consumers are hesitant but may accept this new technology in the future. On the other hand, a significant minority of the respondents are negative towards the installation of these advanced devices in their residences. This level of acceptance towards WEMs contradicts the claims of Gao and Bai (2014), who claimed that people are hesitant to accept devices that use IoT technology, as they may face difficulties in using this type of network. Considering the above, it does not go unnoticed that a problem water utilities have to overcome, is the hesitation and uncertainty of domestic consumers towards the installation of these advanced meters.

First of all, in line with the first hypothesis (H1), the results supported the research of Buchanan et al. (2016) that age will have an effect in the acceptance of consumers towards WEMs, as elderly people might have difficulties in using this modern devices compared to younger population. The decrease in the general acceptance was observed in the 50-64 age group. While previous research (Mondéjar et al., 2011) has stated that people with higher level of education consume more water, the results of this study demonstrate that the educational background of consumers will have an impact in their willingness to accept a WEM in their residence, as most of the consumers who replied positively have a bachelor's degree.

Moreover, in compliance with the second hypothesis (H2), it is made clear that having already a water meter (either conventional or conventional smart meter) installed in the residence, affects the level of acceptance of domestic British consumers towards the installation of a WEM in a positive way, as in that case they are aware of smart metering and feel more familiar with these type of technological devices, despite the fact that they are more advanced than the former. Further to the previous findings, the results indicated that having two or more smart devices can play a significant role in accepting a WEM compared to having one, which agrees with the third hypothesis (H3) of this research study.

This structured survey, revealed the relationship between consumers' preferences for Water Event Meters and their willingness to accept them, as well as it demonstrated a number of barriers and challenges that may emerge from the potential use of these devices in the future. A number of domestic consumers that participated in the survey expressed their fears, regarding issues such as privacy violation, high installation costs and loss of control. The responses of consumers displayed that the majority of them is ready to accept this type of metering if they do not have to pay for installation costs, a fact that agrees with the study of Chawla, Kowalska-Pyzalska and Oralhan, (2020). Similarly, these results reveal that consumers have the same perspective both for Water Event Meters and conventional smart water meters, as the findings of this study do not differ with those presented by Spence et al., (2015), who stated that UK citizens who are concerned about affordability are less likely to consent to sharing their consumption data. It has been argued, that domestic consumers are worried that the feedback provided by conventional smart devices will be monitored by malicious parties (Balta-Ozkan et al., 2013). Privacy concern, constitutes a problem that may reduce the level of acceptance towards the use of these devices in the future. This study provides data that fits with that theory as the majority of respondents do not feel like sharing their data with third parties. On the other hand, this study provides a correlation with the research of Spence et al., (2015) in the UK, as domestic consumers feel more secure knowing that their water consumption feedback will be shared with their water company as they tend to trust more the experts,. In addition, Gao and Bai, (2014) noted, that consumers are worried that having installed an advanced metering that uses IoT technology will lead to loss control of the device and their autonomy will be violated. This research provides a clearer understanding of consumers' perspectives towards the challenge of loss control. Findings from this study suggest, that consumers should be the one responsible for the use of their device as they feel more comfortable in controlling who will have access to their consumption data and in that way it is very likely the percentage of UK citizens who will accept WEMs in the future to increase. Also, consumers who will have full access to their WEM will know which parties will be financially benefited from them, a fact that takes into account the results of a study by Buchanan et al., (2016) that highlighted this type of concern for conventional smart metering. On the contrary, practical barriers such as reliability does not seem to be an issue for domestic consumers as it appears

that they trust the feedback provided my WEMs to be correct.

Keeping in mind the aforesaid, it is made clear that the primary concern of the consumers is the cost of these devices as most of them believe that the installation costs of WEMs would be expensive. On the same wavelength, consumers not only want to buy a WEM in a reasonable price or even free, but they also want to help them in reducing their monthly water bills by monitoring their water consumption from every household appliance. The vast majority of respondents is ready to accept a WEM in the future if they knew that this type of metering will help them from a financial perspective. The previous findings are in line with the research study of Balta-Ozkan et al., (2013) who stated that consumers expect to see considerable savings in the long term with the use of advanced metering.

As far as the four different drinking water perspectives are concerned, the results of the survey revealed an important difference between this research and similar studies. Based on the findings of a case study in Netherlands (Brouwer et al., 2019), the greatest proportion of respondents are looking at the drinking water as an essential human right that should be accessible to anyone. However, the results of this study showed, that the majority of UK citizens who are willing to accept a WEM do not adopt the previous perspective and highlight the importance of having a more sustainable behaviour from both of them individually and their water companies, so more people will be inspired to decrease their environmental impact. What it is of high importance to mention, is that domestic consumers who feel responsible for their own actions and are aware of the environmental challenges caused by the excessive use of water, are likely to accept the installation of a WEM in their residence in the coming years. These results can be explained as consumers who interact with SWMs on a daily or weekly basis are more aware of their water consumption developing in that way their environmental conscience.

The results of this study provide a new insight into the relationship between domestic consumers with different sociodemographic characteristics and their level of acceptance towards an emerging technology that will be used in the future. Analysis of a number of responses, that described people's needs and preferences towards advanced smart water meters such as WEMs was implemented, in order to critically evaluate their attitudes and identify challenges water companies have to overcome, so they increase public acceptance of this type of metering.

Future research could be implemented as the generalizability of the results is limited by the target population of the study participants, the UK citizens. Besides research to other populations, the population of the UK could be monitored as well, in order to see how consumers' attitudes, change over time. Since there is a gap in knowledge between consumers' needs and what WEMs can provide, larger samples could aid water utilities understand peoples' concerns more effectively. Furthermore, despite the fact that surveys are time-saving and cost- effective methods that are capable of collecting a broad range of data from a large number of respondents, their reliability may be questioned as respondents may not feel comfortable providing answers that represent themselves or they do not feel encouraged to provide accurate answers. Also, in this study the given data from the survey cannot be triangulated by another data source as a result of using only one research method. However, this research study provides findings that surrounds a topic that has not been covered yet in detail and is going to be an issue in the future.

In summary, it appears that the majority of domestic British consumers is ready to accept the installation of a WEM in their residence, despite a number of concerns raised by the use of these devices. On the other hand, it would be wrong not to consider those who are hesitant as they consist a large proportion of the target population. Considering the above, it is made clear that consumers should be informed in depth and water companies should communicate with the general public as clearly as possible, about the benefits, the opportunities but also for the challenges (e.g. cost) provided by WEMs, in order to avoid misconceptions regarding this type of metering in the future. Finally, the given results illustrate that the majority of domestic consumers reflect similar concerns both for conventional smart meters and WEMs (i.e. privacy, reliability, loss control). These findings can be explained as WEMs are an emerging technology that has not been released to public yet so people have not understood the full potential and the opportunities provided by these devices and they keen to confuse the new updated devices with the former ones. On the other hand, this considerable similarity reveals some key elements of their preferences and interests that should be considered by water companies before they release WEMs to the public.

6 Conclusion

In the present research, preferences and attitudes of domestic consumers towards the installation of WEMs have been analysed. Findings from a structure survey that was implemented in the UK, revealed some of the key concerns British citizens have, which may act as barriers and affect their level of acceptance towards the installation of these devices. The given data showed that the greatest percentage of participants are ready to accept WEMs in the future and they agree that these advanced meters could provide them with a number of benefits in the long term.

On the other hand, the need for consumer's autonomy and high installation costs may act as limiting factors in the attempt of water companies to provide consumers with advanced metering. Considering that WEMs have not been available for public use yet, further research should be implemented not only both for the population of the UK but also for consumers of other countries. In the case of WEMs, consumers should be better informed before the installation of these devices by their water companies in order to realise their full potential. Moreover, water companies may install a number of pilot WEMs free of charge, so they can test if there is a noticeable behavioural change in the water consumption of their consumers. In conclusion, it is very encouraging that the greater proportion of British citizens looks positively on the installation of WEMs. However, sceptical consumers, especially those with privacy concerns, may need reassurance by water companies that will provide them with greater security and control towards the use of these devices and will make them feel ready to accept them in their residences in the following years.

References

Balta-Ozkan, N., Davidson, R., Bicket, M. and Whitmarsh, L. (2013) 'Social barriers to the adoption of smart homes', Energy Policy. Elsevier Ltd, 63, pp. 363– 374. doi: 10.1016/j.enpol.2013.08.043.

Boyle, T., Giurco, D., Mukheibir, P., Liu, A., Moy, C., White, S. and Stewart, R. (2013) 'Intelligent metering for urban water: A review', Water (Switzerland), 5(3), pp. 1052–1081. doi: 10.3390/w5031052.

Brouwer, S., Pieron, M., Sjerps, R. and Etty, T. (2019) 'Perspectives beyond the meter: A Q-study for modern segmentation of drinking water customers', Water Policy, 21(6), pp. 1224–1238. doi: 10.2166/wp.2019.078.

Buchanan, K., Banks, N., Preston, I. and Russo, R. (2016) 'The British public's perception of the UK smart metering initiative: Threats and opportunities', Energy Policy. Elsevier, 91, pp. 87–97. doi: 10.1016/j.enpol.2016.01.003.

Chawla, Y., Kowalska-Pyzalska, A. and Oralhan, B. (2020) 'Attitudes and opinions of social media users towards smart meters' rollout in Turkey', Energies, 13(3), pp. 1–27. doi: 10.3390/en13030732.

Darby, S. (2010) 'Smart metering: What potential for householder engagement?', Building Research and Information, 38(5), pp. 442–457. doi: 10.1080/09613218.2010.492660.

EC, C. (2019) https://www.waterfall-iws.com/.

Gao, L. and Bai, X. (2014) 'A unified perspective on the factors influencing consumer acceptance of internet of things technology', Asia Pacific Journal of Marketing and Logistics, 26(2), pp. 211–231. doi: 10.1108/APJML-06-2013-0061.

Georgiev, A. and Schlögl, S. (2018) 'Smart Home Technology: An Exploration of End User Perceptions', Innovative Lösungen für eine alternde Gesellschaft: Konferenzbeiträge der SMARTER LIVES 18, (August).

Henn, L., Taube, O. and Kaiser, F. G. (2019) 'The role of environmental attitude in the efficacy of smart-meter-based feedback interventions', Journal of Environmental Psychology. Elsevier Ltd, 63(May 2018), pp. 74–81. doi: 10.1016/j.jenvp.2019.04.007.

Horne, C., Darras, B., Bean, E., Srivastava, A. and Frickel, S. (2015) 'Privacy, technology, and norms: The case of Smart Meters', Social Science Research. Elsevier Inc., 51, pp. 64–76. doi: 10.1016/j.ssresearch.2014.12.003.

Karlin, B., Zinger, J. F. and Ford, R. (2015) 'The effects of feedback on energy conservation: A meta-analysis', Psychological Bulletin, 141(6), pp. 1205–1227. doi: 10.1037/a0039650.

Katz, D., Grinstein, A., Kronrod, A. and Nisan, U. (2016) 'Evaluating the effectiveness of a water conservation campaign: Combining experimental and field methods', Journal of Environmental Management. Elsevier Ltd, 180, pp. 335–343. doi: 10.1016/j.jenvman.2016.05.049.

Koop, S. H. A., Van Dorssen, A. J. and Brouwer, S. (2019) 'Enhancing domestic water conservation behaviour: A review of empirical studies on influencing tactics', Journal of Environmental Management. Elsevier, 247(July), pp. 867–876. doi: 10.1016/j.jenvman.2019.06.126.

Krishnamurti, T., Schwartz, D., Davis, A., Fischhoff, B., de Bruin, W. B., Lave, L. and Wang, J. (2012) 'Preparing for smart grid technologies: A behavioral decision research approach to understanding consumer expectations about smart meters', Energy Policy, 41, pp. 790–797. doi: 10.1016/j.enpol.2011.11.047.

Lanz, B. and Provins, A. (2016) 'The demand for tap water quality: Survey evidence on water hardness and aesthetic quality', Water Resources and Economics. Elsevier, 16(October), pp. 52–63. doi: 10.1016/j.wre.2016.10.001.

Lawson, R., Marshallsay, D., DiFiore, D., Rogerson, S. and others (2018) 'The long term potential for deep reductions in household water demand', Ofwat, UK, 44(April). Available at: https://www.ofwat.gov.uk/wp-content/uploads/2018/05/The-long-term-potential-for-deep-reductions-in- household-water-demand-report-by-Artesia-Consulting.pdf.

Liu, A., Giurco, D. and Mukheibir, P. (2015) 'Motivating metrics for household water-use feedback', Resources, Conservation and Recycling. Elsevier B.V., 103, pp. 29–46. doi: 10.1016/j.resconrec.2015.05.008.

March, H., Morote, Á. F., Rico, A. M. and Saurí, D. (2017) 'Household smart water metering in Spain: Insights from the experience of remote meter reading in alicante', Sustainability (Switzerland), 9(4). doi: 10.3390/su9040582.

Mondéjar, J., Cordente, M., Meseguer, M. and Gázquez, J. (2011) 'Environmental behavior and water saving in spanish housing', International Journal of Environmental Research, 5(1), pp. 1–10.

Monks, I., Stewart, R. A., Sahin, O. and Keller, R. (2019) 'Revealing unreported benefits of digital water metering: Literature review and expert opinions', Water (Switzerland), 11(4), pp. 1–32. doi: 10.3390/w11040838.

Montginoul, M. and Vestier, A. (2018) 'Smart metering: A water-saving solution? Consider communication strategies and user perceptions first. Evidence from a French case study', Environmental Modelling and Software. Elsevier Ltd, 104, pp. 188–198. doi: 10.1016/j.envsoft.2018.02.006.

Nash, A. (2019) National population projections: 2018-based.

Ornaghi, C. and Tonin, M. (2015) 'The Effect of Metering on Water Consumption', Policy Note, University of Southampton, (0), pp. 1–9. Available at: https://www.waterwise.org.uk/resource/the-effect-of-metering-on-water-consumption-a-policy-note-2015/.

Price Waterhouse (2019) 'Funding Approaches for Leakage Reduction', (December). Available at: https://www.ofwat.gov.uk/wp- content/uploads/2019/12/PwC-–-Funding-approaches-for-leakage- reduction.pdf.

Readdy, A. (2006) 'Overview of automatic meter reading for the water industry', 31st Annual Qld Water Industry Workshop - Operations Skills, (1), pp. 1–7.

Spence, A., Demski, C., Butler, C., Parkhill, K. and Pidgeon, N. (2015) 'Public perceptions of demand-side management and a smarter energy future', Nature Climate Change, 5(6), pp. 550–554. doi: 10.1038/nclimate2610.

Water Resources Group (2009) 'Charting Our Water Future', Water, June(3), pp. 1–32. doi: samsung/academico/material didatico/sustentabilidade.

Willis, R. M., Stewarta, R. A., Panuwatwanich, K., Jones, S. and Kyriakides, A. (2010) 'Alarming visual display monitors affecting shower end use water and energy conservation in Australian residential households', Resources, Conservation and Recycling. Elsevier B.V., 54(12), pp. 1117–1127. doi: 10.1016/j.resconrec.2010.03.004.

Yang, L., Yang, S. H., Magiera, E., Froelich, W., Jach, T. and Laspidou, C. (2017) 'Domestic water consumption monitoring and behaviour intervention by employing the internet of things technologies', Procedia Computer Science. Elsevier B.V., 111, pp. 367–375. doi: 10.1016/j.procs.2017.06.036.

Appendix

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Appendix A

A.1 Questionnaire

A.1.1 Demographic questions

1) Gender:
- ❑ Male
- ❑ Female
- ❑ Prefer not to say

2) Age:
- ❑ 18 - 24
- ❑ 25 - 34
- ❑ 35 - 49
- ❑ 50 - 64
- ❑ 65 +
- ❑ Prefer not to answer

3) In what region do you live?
- ❑ North West
- ❑ North East
- ❑ Yorkshire and the Humber
- ❑ West Midlands
- ❑ East Midlands
- ❑ East of England
- ❑ South West
- ❑ South East
- ❑ Greater London
- ❑ Wales
- ❑ Scotland
- ❑ Northern Ireland

4) What is you highest level of education
- ❑ No schooling completed
- ❑ Primary school
- ❑ Secondary school
- ❑ High school graduate
- ❑ Bachelor's degree
- ❑ Postgraduate degree
- ❑ Doctorate (e.g. PHD)
- ❑ Other
- ❑ Prefer not to say

5) Including yourself, how many people currently live in your household?
- ❑ 1-2
- ❑ 3-4
- ❑ 5+

6) Do any children (under 18) live in your household?
- ❑ Yes
- ❑ No
- ❑ Prefer not to say

Display This Question:

If Do any children (under 18) live in your household? = Yes

7) You indicated that they are children (under 18) living in your household. Does your household have any children in the following age ranges? (tick all that apply).
- ❑ 0-4 years
- ❑ 5-10 years
- ❑ 11-17 years

8) Which of the following best describes your current residential situation?
- ❑ I own my current residence
- ❑ I rent my current residence (includes student accommodation)
- ❑ I live with my friends or family (no rental contract)
- ❑ Other

Display This Question:

If Which of the following best describes your current residential situation? = I rent my current residence (includes student accommodation)

9) You indicated that you rent your current residence. Does your rent include any of the following utilities (tick all that apply)?
- ❑ Water
- ❑ Electricity and gas
- ❑ Internet
- ❑ None of the above

10) Does your household include anyone with a disability?

- ❑ Yes
- ❑ No
- ❑ Prefer not to say

11) How much do you pay for water and wastewater services?

- ❑ Less than £200 per year
- ❑ £200-400 per year
- ❑ £400-600 per year
- ❑ over £600 per year
- ❑ I don't know

12) In general, how satisfied are you with your household's water services?

- ❑ Very satisfied
- ❑ Somewhat satisfied
- ❑ Not at all satisfied
- ❑ I don't know

A.1.2 Perspectives

A I believe in working collectively towards a more sustainable world. Water companies should do as much as possible to provide tap water in 'green' and sustainable way. Every individual has a responsibility to save water and use it wisely. People will be encouraged to use water more wisely if they have access to information about their own water consumption.	**C** I believe that water is a human right and everyone should have enough to meet their basic needs. Everyone should have access to the same water services; households should not be able to access better services simply by paying for them. I am prepared to save water now in order to help guarantee sufficient water resources for future generations.
B I am concerned about my health, and I think that tap water should be as natural as possible. Substances should be removed from my tap water, even if they are in concentrations much lower than would be considered harmful. Water companies are mainly responsible for providing me with safe tap water, and I shouldn't have to pay for anything beyond that. Sometimes I worry about the quality of my tap water in the future, and its effects on my health.	**D** I value convenience and minimizing hassle. I prefer to think about my tap water as little as possible, and I should be able to use as much as I like. Water companies are responsible for meeting our water needs in the most efficient and affordable way possible. I'm not concerned about the future of water resources; I believe technological progress will solve most problems.

13) Which of the perspectives above do you MOST agree with?

- ❑ A
- ❑ B
- ❑ C
- ❑ D

A.1.3 Demographic questions

14) To what extent do you agree or disagree with the following statements:

	Agree	Neutral	Disagree
I do my best to use as little water as possible	❑	❑	❑
I would like to reduce my household's water bills	❑	❑	❑
People should pay for the amount of water they use	❑	❑	❑
We need to change our lifestyles to live more sustainably	❑	❑	❑

15) To what extent do you agree or disagree with the following statements:

	Agree	Neutral	Disagree
Water saving is useless if not everyone participates	❑	❑	❑
There is enough water in the UK, we will not have to be careful with water for the next 25 years	❑	❑	❑
I would like more information on how to save water at home	❑	❑	❑
I would like to use new tools and technologies to help save water at home	❑	❑	❑

16) To what extent do you agree or disagree with the following statements:

	Agree	Neutral	Disagree
I would like to see detailed data about my household's water consumption	❑	❑	❑
I would like to identify and respond quickly to potential leaks	❑	❑	❑

17) Do you have any of the following water saving measures in your residence? (Tick all that apply)

- ❑ Water efficient shower head
- ❑ Water saver on the kitchen tap
- ❑ Water efficient washing machine
- ❑ Low-flushing toilet
- ❑ Other
- ❑ No water saving measures

18) Does your residence have a water meter?

- ❑ Yes
- ❑ Yes, for the building as a whole, but not for my individual unit
- ❑ I don't know
- ❑ No

Display This Question:
If Does, your residence have a water meter? = Yes
Or Does your residence have a water meter? = Yes for the building as a whole, but not for my individual unit

19) You indicated that a water meter has been installed in your residence. Please tick the statement that best describes the installation of your water meter.

- ❑ It was installed before I moved in
- ❑ It was installed by the property owner
- ❑ The water company required me to install it
- ❑ The water company offered it to me and I accepted
- ❑ I requested / arranged the installation with the water company
- ❑ I requested / arranged the installation with a third party
- ❑ Other _____

Display This Question:
If Does, your residence have a water meter? = Yes
Or Does your residence have a water meter? = Yes for the building as a whole, but not for my individual unit

20) Is your water meter a smart meter?

- ❑ Yes
- ❑ I don't know
- ❑ No

Display This Question:

If A smart water meter (SWM) is a digital meter that monitors how much water your household is using... = Yes is selected

21) Are you able to see or access data from your smart water meter, in order to see how much water your household is using?

- ❑ Yes
- ❑ I don't know
- ❑ No

Display This Question:

If Are you able to see or access data from your smart water meter, in order to see how much water your household is using... = Yes is selected

22) You indicated that you are able to see or access data from your smart water meter, in order to see how much water your household is using. How do you see or access the data?

- ❑ Through a display in my residence
- ❑ Through a web site
- ❑ Through an app
- ❑ Other _____

Display This Question:

If Are you able to see or access data from your smart water meter, in order to see how much water your If Are you able to see or access data from your smart water meter, in order to see how much water, you... = Yes

23) How often do you check this data?

- ❑ Daily
- ❑ 2-3 times a week
- ❑ Once a week
- ❑ Every other week
- ❑ Once a month
- ❑ Other _____

24) Do you or any other members of your household have any of the following "smart" devices (tick all that apply)?

- ❑ Smart energy meter with energy consumption monitor
- ❑ Smart phone
- ❑ Smart speaker
- ❑ Smart home heating system
- ❑ Smart lighting system
- ❑ Smart wearable device (e.g. fitness tracker)
- ❑ Other _____

25) If you were given the choice of having a Water Event Meter in your residence, would you accept it?

- ❑ Yes
- ❑ Maybe
- ❑ No

26) Would the following conditions make you more or less likely to accept a Water Event Meter in your residence?

	More likely to accept	No change	Less likely to accept
If it was provided free of charge by my water company	❑	❑	❑
If I could purchase or rent it from my water company	❑	❑	❑
If I could purchase or rent it from a third party	❑	❑	❑
If I could control who had access to the data	❑	❑	❑
If it helped me reduce my water bills	❑	❑	❑
If it reduced my insurance bills	❑	❑	❑

27) To what extent do you agree with the following statements about Water Event Meters (WEMs)?

	Agree	Neutral	Disagree
I see no benefits from WEMs	❑	❑	❑
WEMs probably cost a lot	❑	❑	❑
It's ok for third parties to have access to the data from WEMs	❑	❑	❑
It's ok for water companies to have access to the data from WEMs	❑	❑	❑
I believe that the data from WEMs is likely to be correct	❑	❑	❑

Appendix B

B.1 Consumption of metered and unmetered households

Figure B-1: Per capita consumption of metered and unmetered households in the UK. Source: (Lawson et al., 2018)

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

B.2 Percentage of metered households by 2045

Figure B-2: Estimated percentage of metered household by 2045 in the UK. Source: (Lawson et al., 2018)

Geographic area	% of homes metered
England and Wales	86%
South East	88%
South West	88%
Central	91%
North	77%

Appendix C — Cross-tabulation tables

C.1 Cross-tabulation of annual water and waste-water bill with two different groups of British consumers.

Table 1: Cross-tabulation of annual water and wastewater bill with two different groups of people: "Group A" corresponds to British consumers who have not a water meter in their residence while "Group B" to consumers who use a water meter (either conventional or conventional smart water meter NOT WEM). Participants who answered "I don't know" where not included in the analysis.

	Water meter		
Monthly electricity bill	Group A (No)	Group B (Yes)	Total
Less than £200 per year	19	33	52
£200-400 per year	87	116	203
£400-600 per year	54	52	106
Over £600 per year	16	19	35
Total	**176**	**220**	**396**

C.2 Cross-tabulation of overall satisfaction with household's water services of domestic consumers with three different groups of British consumers.

Table 2: Cross-tabulation of the overall satisfaction with domestic water services of the participants with three different groups of British consumers: Group 0 corresponds to consumers who do not accept a WEM in their homes, Group 1 to consumers who accept a WEM and "Group 2" to those who answered "Maybe".

	WEM			
Overall satisfaction with domestic water services	Group 0 (No)	Group 1 (Yes)	Group 2 (Maybe)	Total
Very satisfied	28	132	101	261
Somewhat satisfied	21	113	115	249
Not at all satisfied	5	16	15	36
I don't know	3	3	6	12
Total	**57**	**264**	**237**	**558**

C.3 Cross-tabulation of the gender with the willingness of participants to accept a WEM

Table 3: Cross-tabulation of the gender of participants with three different groups of British consumers: Group 0 corresponds to consumers who do not accept a WEM in their homes, Group 1 to consumers who accept a WEM and "Group 2" to those who answered "Maybe".

Gender	WEM			Total
	Group 0 (No)	Group 1 (Yes)	Group 2 (Maybe)	
Male	28	139	99	266
Female	28	125	138	291
Total	**56**	**264**	**237**	**557**

C.4 Cross-tabulation of age in years of people with three different groups of British consumers: Group 0 corresponds to consumers who do not accept a WEM in their homes and Group 1 to consumers who accept a WEM while "Group 2" to those

Table 4: Cross-tabulation of age in years of people with three different groups of British consumers: Group 0 corresponds to consumers who do not accept a WEM in their homes and Group 1 to consumers who accept a WEM while "Group 2" to those who answered "Maybe"

Age (years)	WEM			Total
	Group 0 (No)	Group 1 (Yes)	Group 2 (Maybe)	
18-24	1	33	31	65
25-34	9	64	32	105
35-49	15	88	84	186
50-64	20	42	55	116
65 +	11	36	35	82
Total	**56**	**264**	**237**	**555**

C.5 Cross-tabulation of British consumers who have or have not installed a WEM in their residence with three different groups of people

Table 5: Cross-tabulation of British consumers who have or have not installed a water meter in their residence (Either conventional or conventional smart meter) with three different groups of people: "Group 0" corresponds to people who do not accept a WEM in their residences, "Group 1" to consumers who have accepted a WEM and "Group 2" to those who answered "Maybe".

	WEM			
Water meter	Group 0 (No)	Group 1 (Yes)	Group 2 (Maybe)	Total
Consumers who have a water meter	18	140	83	241
Consumers who do not have a water meter	34	90	99	223
I don't know	5	23	35	63
Total	**57**	**253**	**217**	**527**

C.6 Cross – tabulation of the four different drinking water perspectives with three different groups of British consumers.

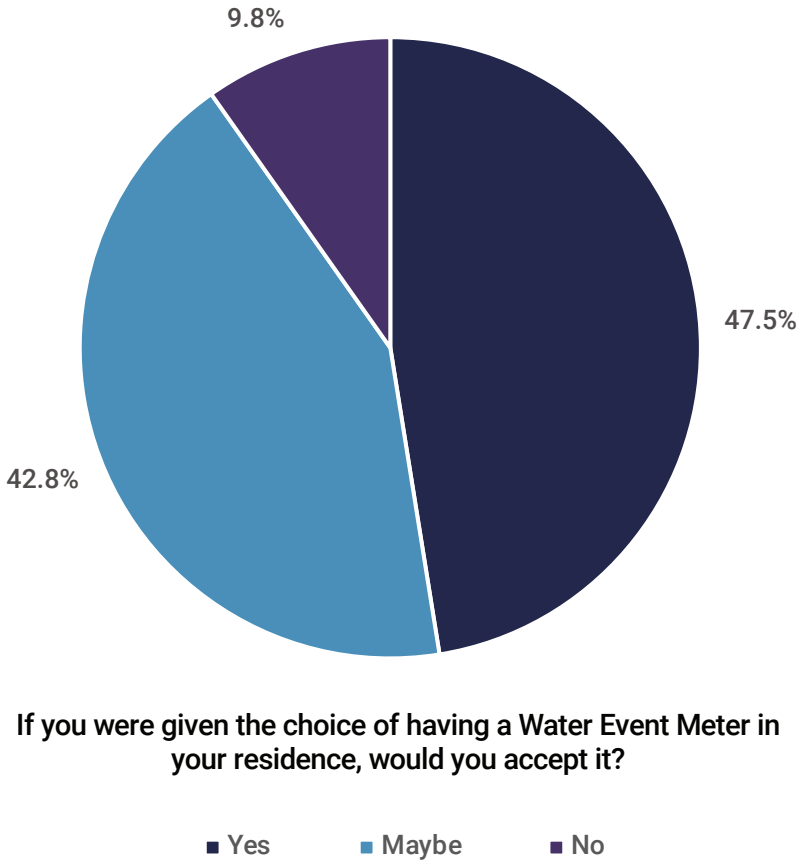
Table 6: Cross-tabulation of the four different drinking water perspectives with three different groups of British consumers: Group 0 corresponds to consumers who do not accept a WEM in their homes, Group 1 to consumers who accept a WEM and "Group 2" to those who answered "Maybe".

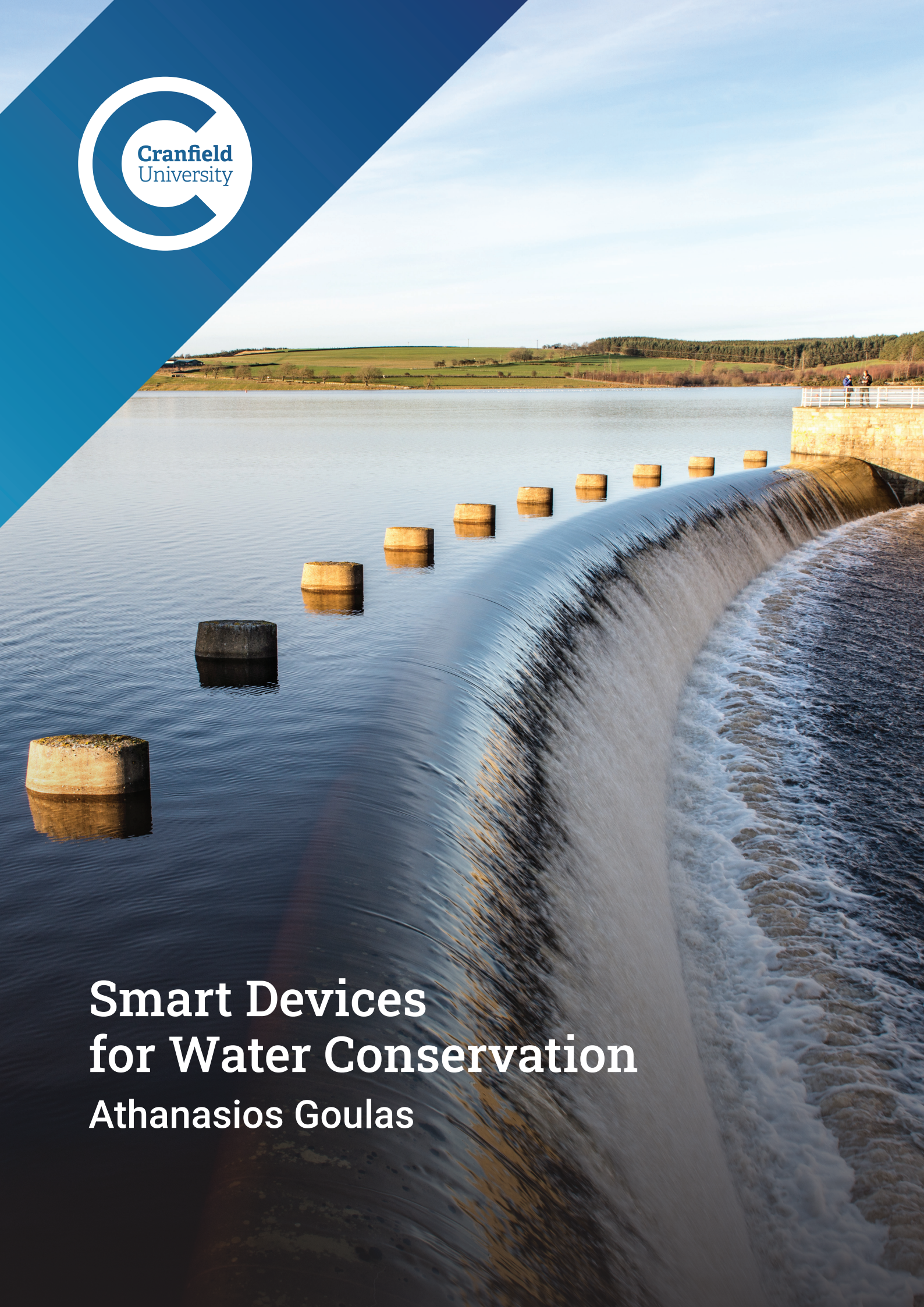
	WEM			
Perspectives	Group 0 (No)	Group 1 (Yes)	Group 2 (Maybe)	Total
A	15	100	61	176
B	9	64	59	130
C	19	78	94	190
D	14	22	23	59
Total	**57**	**264**	**237**	**555**

Appendix D

D.1 Graph that depicts the general acceptance of participants towards the installation of WEMs

Figure D-1: Pie chart that illustrates the acceptance level of British consumers towards the installation of WEMs.





Smart Devices for Water Conservation

Athanasios Goulas