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Design implementation and evaluation of a mobile application for sustainable water consumption

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Abstract – Italiano

Una piccola percentuale di acqua sulla terra è contenuta nei ghiacciai e nelle calotte polari, mentre la maggior parte è presente come acqua salata negli oceani e nei mari. Pertanto, solo una piccola percentuale di acqua è potabile. La consapevolezza sul consumo di acqua e sul risparmio idrico è fondamentale per risparmiare acqua e per proteggere il nostro ambiente e la nostra specie.

SmartH2O è un progetto finalizzato ad aumentare la consapevolezza del consumo di acqua dei cittadine, fornendo suggerimenti e altri stimoli per aiutare il cambiamento nel comportamento dei clienti dei servizi idrici in tutto il mondo, dopo che questi hanno installato contatori intelligenti nelle loro abitazioni, fornendo un feedback costante del loro consumo. Questa tesi si propone di migliorare l'impatto che la piattaforma SmartH2O ha sulle persone mediante la creazione e distribuzione di una versione mobile dell'applicazione SmartH2O, che affianca il portale web e mira a raggiungere più efficacemente l'attenzione dell'utente con le notifiche push e con un'interfaccia più semplice, portatile e interattiva.

La tesi svolge uno studio delle teorie motivazionali, dei modelli di incentivazione e dei metodi di coinvolgimento; quindi riporta le scelte implementative avvenute nella versione web dell'applicazione SmartH2O. Inoltre, questa tesi studia in modo approfondito i presupposti scientifici e tecnologici necessari per realizzare un'applicazione seguendo il modello di progettazione Android, rendendola compatibile con la maggior parte dei dispositivi e capace di raggiungere il maggior numero di utenti SmartH2O. Inoltre, presenta in dettaglio ilprocesso di sviluppo delle interfacce atte a creare una continuità con il portale, l'attuazione della gestione delle notifiche push e gli schemi di sincronizzazione tra dati mobili e dati di back-end seguiti.

Infine, questo lavoro illustra i risultati ottenuti da una prima analisi della versione web del portale ed una prima analisi basata sui risultati qualitativi forniti da alfa tester sull'applicazione mobile, portando ad una discussione preliminare sull'impatto dell'applicazione e sulle future possibilità di miglioramento.

Keywords: Consumo idrico, Smart metering, Gamificazione, Interfacce di visualizzazione, Analisi big data, Profilazione utenti, SmartH2O, User centered design, Android, Google Cloud Messaging, Notifiche push, Sviluppo mobile.

Abstract – English

A small percentage of Earth's fresh water is locked in glaciers and ice caps, while the widest part is present as salt water. Therefore, a few percentage of water on Earth is available for drinking. Awareness on water consumption and water saving is fundamental to save water and to protect our environment and our specie.

SmartH2O is a project aimed to increase the awareness of the water consumption in its users, providing tips and other stimuli to help the change in behavior of the customers of the water utilities all over the world, having installed smart meters in their habitations leading them to receive constant feedback of their consumption. This thesis focus is to analyze the impact such platform can have on people and to help the distribution of the SmartH2O social awareness application with a mobile version aimed to better reach user's attention with notification and a simpler, portable and interactive UI.

A study of the motivational theories, incentive models and engagement methods have been done, then all the implementation choice done in the web version of the SmartH2O application have been reported. Furthermore, this thesis covers in depth the scientific and technological background required to implement an Android application following the Android Design Pattern, working on the most majority of devices reaching the biggest number of SmartH2O users. Then, it presents in details all the execution of the development of a UI that could create a continuity with the portal, the implementation of the push notification management and the synchronization patterns followed.

Finally, this work discusses the results obtained by a first analysis of the web portal version and an early analysis based on qualitative results provided by alpha testers of the mobile application, leading to a premature discussion about the impact of the application and the future possibilities of improvement.

Keywords: Water management, Smart metering, Gamification, Visualization interfaces, Big data analytics, User profiling, SmartH2O, User centered design, Android, Google Cloud Messaging, Push Notifications, Mobile Development.

Estratto in lingua italiana

SmartH2O è un progetto finanziato dall'Unione Europea, il cui obiettivo è quello di sviluppare una piattaforma ICT per migliorare la gestione del consumo dell'acqua nelle reti urbane e peri-urbane grazie all'utilizzo integrato di contatori intelligenti e computazione sociale, sulla base di modelli avanzati di analisi del comportamento dei consumatori. SmartH2O mira a collegare in modo significativo e utile utenti e servizi idrici, creando un sistema di feedback circolare, fornendo le informazioni agli utenti sul loro consumo di acqua in tempo reale.

Gli obiettivi di questa tesi sono la progettazione, lo sviluppo, l'implementazione e la verifica dell'impatto di un'app mobile mirata a creare continuità con il portale, già utilizzato dai consumatori, nel quadro del progetto SmartH2O.

L'applicazione mobile contiene le stesse caratteristiche innovative già presenti nella piattaforma web, come ad esempio la visualizzazione e l'interattività dei dati "gamificati", volti a promuovere il cambiamento comportamentale degli utenti e aumentare la loro consapevolezza riguardo al consumo idrico, obiettivi dell'intero progetto.

Incentivare gli utenti a impegnarsi in azioni di risparmio dell'acqua è di importanza cruciale per il successo della piattaforma SmartH2O perché il comportamento dimostrato riguardo il consumo è - come molti altri comportamenti che hanno un impatto sull'ambiente - principalmente guidato dall'abitudine che avviene senza pensiero attivo da parte dell'utente.

La prima sezione della tesi (secondo capitolo) illustra le principali teorie motivazionali che sono state studiate fino ad oggi, spiegando i principali motori del comportamento umano, e poi si concentra nel descrivere la soluzione e le scelte metodologiche che sono state impiegate in SmartH2O: la "gamification", ovvero l'uso di elementi tipici dell'ambiente di gioco in contesti di non-gioco.

Dal punto di vista tecnico, la costruzione del sistema SmartH2O è stata sfida dovuta a diversi fattori derivanti dalla natura ibrida della soluzione. Nel terzo capitolo di questa tesi è riportata una panoramica sull'architettura e i principali moduli della piattaforma, gli obiettivi e le motivazioni che hanno portato ad una tale struttura e i componenti chiave di SmartH2O.

La versione mobile di SmartH2O è sviluppata in linguaggio nativo Android, basato su Java. Il quarto e il quinto capitolo della tesi spiegano nel dettaglio le scelte che hanno portato alla decisione dello sviluppo Android, le librerie utilizzate e i principali protocolli di comunicazione usati, come anche i meccanismi di sincronizzazione e i componenti dell'app. Nello specifico, è riportata anche un'attenta analisi dei requisiti, dei casi d'uso e della UI.

Il sesto capitolo riporta, in entrambi i casi di studio (svizzero e spagnolo), i risultati ottenuti con l'utilizzo dell'applicazione web di SmartH2O da parte utenti reali. A causa del tempo limitato, la valutazione e analisi della versione mobile di SmartH2O non è stata possibile, in quanto l'app non è stata rilasciato al

pubblico al momento di questa tesi, bensì solo ad un ristretto numero di alfa tester. Per questo motivo, una prematura analisi dell'impatto della versione mobile sugli utenti della piattaforma è stata possibile grazie ai feedback valutativi forniti dai suddetti tester, che hanno risposto ad un questionario creato ad-hoc per questa tesi, lasciando possibile un primo confronto tra le due versioni di SmartH2O: mobile e portale. Infine, alla luce dei risultati ottenuti, sono state fatte delle prime ipotesi su futuri miglioramenti da parte della piattaforma web, di quella mobile e di tutta l'architettura in generale, per rendere l'applicazione più performante, utile e accattivante e adempiere agli obiettivi prefissati: cambiare l'atteggiamento degli utenti per quanto riguarda il consumo dell'acqua.

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1 Introduction

1.1 Background: The SmartH2O Project

The SmartH2O project is a project founded by the European Union which develops an ICT platform for improving the management of urban and peri-urban water demand thanks to the integrated use of smart meters, social computation, and dynamic water pricing, based on advanced models of consumer behavior [67]. SmartH2O aims to link in a meaningful and useful way users and water utilities, creating a circular feedback system between them, providing the users information on their water consumption in real time and, then, allowing Water Utilities to improve their strategies to reduce or reallocate water consumption. The mere water measurement, done usually twice a year, can be used to collect aggregate user data but won't allow the study of the behavior of single users or neighborhoods. Smart water meters allow the collection of data more frequently, thus also to gather real time information on the state of the network. Such information can be pushed to the user to increase his awareness on water use. Studying also behavioral and motivational theories and mechanisms, applied to the actual behavioral traces of the individual users utilizing the architecture, can lead to the creation of new methodologies and mechanisms to increment awareness, incentivize users in water saving and let them being the promotors of behavioral change in water consumption. Using a social computing approach, SmartH2O aims to be an effective mechanism of consciousness on the subject of water consumption, sustainability and water wasting issues.

SmartH2O social awareness web and mobile app aims to help consumers save water by raising social awareness. One of the goals of this scenario is to allow consumers to monitor their water usage online with social gamification mechanisms, increasing individual and collective awareness.

1.2 Objectives and organization of the thesis

The objectives of this thesis are the design, development, deployment and verification of a mobile app targeted to water consumers, in the framework of the SmartH2O project.

The mobile app will contain suitable features, such as data visualization and activity gamification, aimed at promoting behavioral change in the targeted users and will complement an existing web portal, already implemented for the same goal.

To reach its objectives, first the thesis performs a survey of the background of motivational theories and behavioral change methodologies, studied in order to build a solid and pervasive architecture for SmartH2O social awareness application. Then a review of the role of persuasive games for sustainability has been done, leading of the current architecture based on such researches. The

solution adopted is built on an understanding and modelling of consumers' behavior on the basis of historical and real-time water usage data, predicting how the consumer behavior can be influenced by various water demand management policies, from water savings campaigns, to social awareness campaigns, and raising the awareness of consumers on their water usage habits and stimulates them to reduce water use. With a deep understanding of what has been done architecturally on server side, the last section of this thesis is aimed to explain how and why the mobile version of SmartH2O social awareness application has been created. Based on the goal to change the behavior of customers toward a water consumption awareness and a willing to save water, the last chapter of this thesis will explain how the application has helped users to reach such awareness, studying the behavior taken by them using the web application and the results of an early qualitative questionnaire, drawing conclusions on how to improve the user experience in order to better implement behavioral change methodologies.

1.3 Results

This thesis focused on providing the smartH2O project with a complete mobile version of the web portal to improve the impact that the project would have in water consumption awareness, promoting water efficiency on the consumer community by providing educational tips and videos, interacting with the gamified part of the application and designing strategies for sustainable water management by providing insight of consumer groups.

In particular, this thesis aimed:

- To design and implement mobile version for the SmartH2O project, following the well-known Android design pattern.
- To improve user engagement with the platform by keeping constant information flows through a push notification management to alert the user about events related with the platform or its consumption, and provides concrete pieces of information to save water.
- To design an application that must be robust, performing and constantly synchronized and up-to-date with the portal version to permit a continuity and congruency of the user experience.

In addition, this thesis wanted to make an important contribution to the SmartH2O mission of raising consumers' awareness on their water usage habits, and to the understanding and modeling users' behavior using the metered consumption and users' profile information. This thesis project in combination with the overall project effort achieved, in time, the ultimate goal of creating a power and sophisticated tool to reduce water waste and manage water efficiently.

In order to achieve its objectives this thesis work adopted the practices and methodologies used in the SmartH2O project, including the user-centered design

approach to derived the user needs, and define the mobile app functional and not functional requirements based on those needs.

On the technological side, this thesis project adopted the Android Design Pattern, fitting the most majority of Android devices from different price ranges. In this way, the application could reach the largest number of users of the SmartH2O web portal. Developed in java language, it was possible to implement all the services accessed through the system's APIs and also to all the SmartH2O databases.

The evaluation of the results of the use of SmartH2O application by the users has been done and reported at the end of this thesis. To do so, the same validation metrics and methodologies that have been already done for the first release of the web portal has been done. In details, for the web portal, has been reported the results of a series of trial periods after which the impact of the solution is evaluated in conjunction to the answers to a qualitative questionnaire, whilst for the mobile application, results by the same questionnaire given to alpha testers have been collected and compared to the results of the questionnaire filled about the web portal.

1.4 The water management process

In literature, there are several management policies for what concerns the demand of water consumption by residential customers. Grafton et al. [51] have distinguished three categories of measures household level: water restriction [14], i.e. compulsory regulations on water use according to availability and seasons; water tariffs control [45], i.e. prices based on user's elasticity; and voluntary measures, like domestic water saving norms promoted by education or informative campaigns [35, 62]. Approaches based on price or stringent non-price prescriptive are good in the short-term [18], on the other hand awareness approaches work on the long-term because they require a change in user's behavior [25].

Water consumption has been studied for years using a top-down approach based on pattern analysis at the city or district level and relying mostly on periodic billing data [52, 26] to infer climate, season [37] and calendar dependencies [48]. But an accurate measurements of end-user water consumption have been demonstrated to be essential to evaluate alternative management measures [63]. More recently, the development of smart metering systems allowed increasing temporal and spatial resolution and disaggregation of water consumption into sub-daily events at the household level [62, 46, 50]. This mechanism enabled a much detailed understanding of water consumption, including economic and socio-demographic factors [51, 65] such as income, family composition, lifestyle [32], property characteristics [43], environmental and water conservation attitude [24, 40].

Next chapter will introduce the main concepts of incentive models and engagement methods and will explain the motivational theories on which all the SmartH2O social awareness application – and thus the mobile version of it – is based.

2 Incentive models and engagement methods

Incentivizing users to engage in water saving actions is of crucial importance to the success of the SmartH2O social awareness application [88] because water consumption behavior is – like many other behaviors that have impact on the environment – mainly a habit-driven behavior that occurs without active thinking [11].

This section of the thesis will outline the main motivational theories, explaining the main drivers of human behavior, and then will focus on one solution that has been employed in many different application areas to incentivize users, and which has been adopted in SmartH2O: gamification, the use of game design elements in non-game contexts [49].

2.2 Relation between motivation and games: psychological theories

In this section, the motivation theories in the context of games and gamified applications are examined. Motivation may be defined as the energization (i.e., instigation) and direction of behavior [22]. Motivation initiates, guides and maintains goal-oriented behavior, what causes us to act [86]. It represents the reasons for people's actions, desires, and needs. People are moved to act by very different types of factors, with highly varied experiences and consequences. People can be motivated because they value an activity or because there is strong external coercion. They can behave from a sense of personal commitment to excel or from fear of being watched [19].

Research on gamification has been heavily influenced by the distinction between extrinsic and extrinsic motivation, which was introduced by [7] in their self-determination theory. Intrinsic motivation refers to doing something because it is inherently interesting or enjoyable [17]. It relates to activities pursued for inherent satisfaction rather than for some separable consequence. Humans, in their healthiest states, are active, curious, and playful creatures, ready to learn and explore, without requiring extraneous incentives to do so.

- **Intrinsic motivation** exists not only within the individual but also in the relation between individuals and activities; people are intrinsically motivated for some activities and not others, and not everyone is intrinsically motivated for a particular task [17].
- **Extrinsic motivation**, on the other hand, refers to doing something because it leads to a separable outcome [17], generally came from the "outside". Common extrinsic motivations include rewards (e.g. money or grades) for showing a desired behavior, and threats of punishment following misbehavior. Competition is another extrinsic motivator because it encourages the performer to win and to beat others, rather than simply

enjoying the intrinsic rewards of the activity. Such rewards can provide satisfaction and pleasure that the task itself may not provide. An extrinsically motivated person might work on a task even though the person has little interest in it because of the anticipated satisfaction the person will get from some reward [66].

Social psychological research indicates that the two mentioned types of motivation do not properly work together. Some works show that once extrinsic motivation is provided, the user's intrinsic motivation will decrease [21]. Pink [53] argues that some extrinsic motivators like money do not work well for creative and complex tasks. Instead, for such tasks, long-term social status rewards can be more effective. In addition, using extrinsic motivation for controlling behavior often creates negative feelings, while intrinsic motivation is often more meaningful to people and results in a positive change of a person's mindset [15].

In the specific context of gamification research, Richter, Raban and Rafaeli [78] following Vassileva [60] presented a spectrum of motivational theories that range from extrinsic through social to intrinsic motivation. (Figure 1)

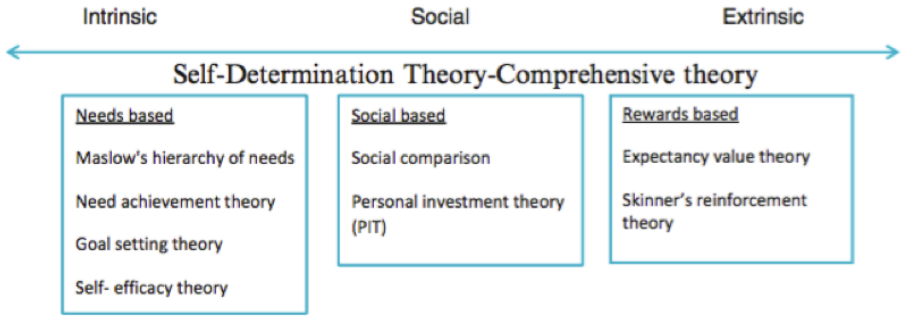

Figure 1: Spectrum of motivational theories [78]

At one extreme of this spectrum, there is the extrinsic motivation, the focus of *Expectancy Value Theory and Skinner's Reinforcement Theory*, which explains the motivation to perform actions or present behaviors that induce extrinsic rewards [60]. The other end of the spectrum contains the intrinsic motivations, on which the need-based theories *Maslow's Hierarchy of Needs, Atkinson's Need Achievement Theory*, *Bandura's Self-Efficacy Theory* and *Goal Setting Theory* focus. The theories in between, explain the social motivation of games, including the theories of Festinger's *Social Comparison and Personal Investment Theory* (PIT) [2]. Last, the Self-determination theory extends from the one end to the other as it includes both intrinsic and extrinsic motivation.
In next pages of the thesis, there will be a navigation through all the theories included in Figure 1. A highlight on how these theories influence the design of gamified applications – and SmartH2O – and the choice of particular game mechanisms will be done.

2.2.1 Needs-based motivation theories

One of the earliest theories of motivation, become the basis for the effort to bring the theory in the (computer) game's context and illustrate player needs, is Maslow's *Hierarchy of Needs* [1]. It postulates that human behaviors are driven by the desire to satisfy physical and psychological needs and proposes a five-level scheme of needs. It starts from physical needs and needs for safety, security, and progress to more complex needs such as desire for belongingness, self-esteem and self-actualization. A person should satisfy the first levels before progressing to the complex ones, which are produced by positive incentives [78].

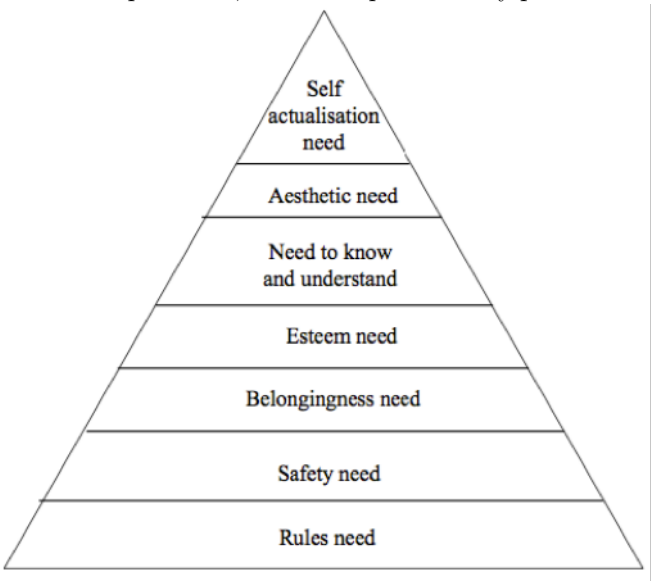

Figure 2: Hierarchy of the players' needs [27]

That perfectly fits game players: at the bottom level players seek to understand the rules of the game (*rules need*), the most fundamental need in order to be motivated to play [27]. When this is fulfilled, players move on to the need to feel safe and secure (*safety need*): they need information to stay in the game long enough to win and avoid being knocked out. Then there is the *belongingness need*, the level where the players need to feel comfortable and to know it is possible to win. Moving on, they want to feel good when playing the game and find information on how to achieve *esteem need* and have full control over the game. After that, they start to expect a greater challenge and need to know and understand more about the game, such as different strategies. The sixth level is an *aesthetic need* reflecting the call for good graphics, visual effects etc. Finally, as part of the *self-actualization need*, players want to be able to do anything within the game rules and constraints [27, 78].
According to the *Need Achievement Theory* [4], Achievement behavior is directed at developing or demonstrating, to oneself or to others, a high ability rather than a low one [78]. Furthermore, achieving success and avoiding failure are

two separate motives that affect the level of difficulty that people choose to undertake. In particular, people highly motivated to succeed prefer intermediate difficulty tasks. On the other hand, if the motive to avoid failure is stronger, people tend to prefer either very simple or very difficult tasks [4, 78].
This theory is the basis for the *Goal Setting Theory*, which claims that difficult, specific, context- appropriate, and immediate - rather than long-term - goals, motivate to achieve more [33]. A goal is what the individual is trying to accomplish, the object or aim of an action. Goals affect the performance by directing attention, assembling effort, increasing persistence and belief in ability to complete a task [6]. Three features affect goal efficiency: proximity, difficulty, and specificity. Good goal setting incorporates the *SMART* criteria, i.e. goals should be specific, measurable, accurate, realistic, and timely. A goal should be moderate, i.e. not too hard or too easy to complete, and at the same time people want to feel that there is a substantial probability of success. Specificity concerns the description of the goal: the goal should be objectively defined and intelligible for the individual. A game context usually defines a specific goal for a player. The *goal-setting theory* is based on the notion that payers (individuals) often strive to reach a clearly defined end-state and, often, this end-state is a reward itself.
Self-efficacy theory [5] focuses on the individuals' belief in their ability to succeed in specific situations. The theory states that self-efficacy plays a major role in how a person approaches goals, tasks and challenges: self-efficacy levels can enhance or impede motivation. People with high self-efficacy choose to perform more challenging tasks, investing more effort and persisting; and when failure occurs, they recover more quickly and maintain the commitment to their goals [12, 78].
In the end, Reiss, in his basic desires theory, identifies sixteen basic desires, studied among more than 6,000 people, which guide a large part of human behavior. Those motivate our actions and define our personalities and are *Acceptance*, *Curiosity*, *Eating*, *Family*, *Honor*, *Idealism*, *Independence*, *Order*, *Physical activity*, *Power*, *Romance*, *Saving*, *Social contact*, *Social status*, *Tranquility*, *Vengeance*. Gamification has the potential to incentivize users by appealing to one or more of these basic human desires. Then, such a variety of basic human desires also draws the attention towards differences between users, as different users will be motivated by different desires, requiring an incentive model that takes into account these different motivations.

2.2.2 Socially-based motivation theories

The social aspect is also significant in games [33] and this has been particularly obvious in gaming applications integrated in social networks like Facebook, which offer a setting for socialization in a playful manner, attracting huge popularity [78].
Two theories have elaborated the social side of games. The first is the *Social Comparison Theory* [2], which is based on the idea that people tend to compare themselves with others, who they consider as similar to them, in order to evalu-

ate or enhance some of their personal aspects, such as their beliefs and abilities [60, 78]. It can explain the motivational effect of the leader-board pattern in game mechanics and has been the inspiration for design of incentive mechanisms in several research projects. Then, Vassileva [60] noted that comparison - or reputation - based mechanisms increased the contribution from the users in several systems and claimed that it could be a powerful incentive to increase effectively contributions to online communities.
The second theory that has elaborated the social side of games is the *Personal Investment Theory* [23]. It suggests that the level to which one will invest personal resources of effort and time for a task depends on personal incentives, beliefs regarding oneself, and available alternatives [78]. The theory defines three basic components of critical meaning to determining personal investment in specific situations: personal incentives (intrinsic or extrinsic), sense of self and perceived options [78, 23]. Furthermore, personal incentives can contain among others task incentives (e.g. skill improvement), ego incentives (e.g. wish to perform better in comparison with others), social incentives (e.g. affiliation with others) and extrinsic rewards. The sense of self is referring to perceptions, beliefs and feelings related to competence, goal-directedness, self-reliance and social identity. Last, perceived options are alternatives, available and appropriate and often influenced by social aspects [78].

2.2.3 Reward-based motivation theories

Reward-based (or extrinsic) motivation are created through external factors, rewards or incentives and, in this category of theories [78], Vassileva [60] include the *Expectancy Value Theory* and the *Reinforcement theory*. The first relates to the strength of motivation to strive for a certain goal, the expectations to attain the desired goal, and the incentive value of that particular goal [78].
Expectancies and values are assumed to influence directly achievement choices and to have an impact also in performance, effort, and persistence. Expectancies and values are assumed to be influenced by task-specific beliefs such as ability beliefs, the perceived difficulty of different tasks, and individuals' goals and affective memories, which are in turn influenced by individuals' perceptions of their own previous experiences and socialization influences [20].
Eccles et al. [20] defined different components of achievement values:

- *Attainment value* or *importance*: is defined as the importance of doing well on a given task.
- *Intrinsic value*: is the enjoyment one gains from doing the task; doing tasks that are intrinsically valued, has psychological impact and mostly positive. It is similar to the construct of intrinsic motivation as defined by Deci and Ryan [7] because it concerns doing a task out of interest and enjoyment.
- *Utility value* or *usefulness* of the task: refers to how a task fits into an individual's plans (e.g. taking a math class to fulfil a requirement for a science degree). It's similar to the "extrinsic" reasons for engaging in a task described by Deci and Ryan [7], such as doing a task not for its own

sake but to reach some desired outcome and thus this construct can be tied to the construct of extrinsic motivation.
- *Cost*: refers to how the decision to engage in one task limits access to other activities, as assessment of the effort and the emotional cost to accomplish the activity.

The *Reinforcement Theory*, proposed by Skinner [3], explains the motivation to perform actions or behaviors that lead to extrinsic rewards. It states that individual's behavior with negative consequences tends not to be repeated as people generally seek out and remember information that provides cognitive support for their pre-existing attitudes and beliefs. Then, he noticed that continuous reinforcement establishes desired behaviors quicker than partial reinforcement, but, once removed, the desired behavior extinguishes fast [78].

2.2.4 Self-Determination Theory

Self-Determination Theory (SDT) represents a broad framework for the study of human motivation and personality. It articulates a meta-theory for framing motivational studies, a formal theory that defines intrinsic and extrinsic sources of motivation, and a description of the respective roles of intrinsic and types of extrinsic motivation in cognitive and social development and in individual differences. It also focuses on how social and cultural factors facilitate or undermine people's sense of volition and initiative, in addition to their well-being and the quality of their performance [84].
Intrinsically motivated behaviors are performed out of person's interest and satisfy the inherent psychological needs for competence and autonomy that are the prototype of self-determined behavior. Extrinsically motivated behaviors - those that are executed because they are instrumental to some separable consequence - can vary in the extent to which they represent self-determination [19].
SDT discusses three psychological needs:

- *Autonomy*: the ownership of one's behavior, the ability to make choices according to own free will.
- *Competence*: the ability to produce desired outcomes and to experience effectiveness and mastery.
- *Relatedness*: is experienced when a person feels connected.

Conditions supporting the individual's experience of those psychological needs are supported to provide the most willful and high quality forms of motivation and engagement for activities, including enhanced performance, persistence, and creativity [84]. On the other hand, when these needs collide, motivation and well-being diminish [17]. In addition, SDT [84] proposes that the degree to which any of these three psychological needs is unsupported or thwarted within a social context will have a robust detrimental impact on wellness in that setting.

2.2.5 Game Design and Motivation theories

There is a multitude of games having different structures and based on diverse concepts, but they can all be represented by three underlying dimensions [30]:

- **Dynamics**: different patterns based on psychological motivations, like challenge created by time pressure and opponent play, fellowship encouraged by shared information between players, etc.;
- **Mechanics**: the various actions, behaviors and control mechanisms allowed to the player during the game, together with the features that make the progress visible, like levels, points, leader-boards, goals, virtual goods;
- **Aesthetics**: the overall experience – response of the player evoked when the player himself interacts with the game, like pride, envy, surprise, connection, satisfaction, fun, etc.

The explanation of game mechanics is based on all the aforementioned motivation theories and those mechanics are mapped correspondingly [78]. The motivational effect of the leaderboard, for example, can be explained with the social comparison theory and the tendency of people to compare themselves with others. Another example of mapping mechanic-motivation theory is the badge mechanism: it can represent one's achievement advertisement as well as a goal-setting device.
Gamified applications can offer extrinsic rewards such as levels, points, and badges to improve engagement on the one hand, while on the other hand they can strive to raise feelings of achieving mastery, autonomy and sense of belonging [78].
In line with social comparison theory, social motivations are triggered by providing social recognition and status in the player community through levels, badges, and leaderboards. This exemplifies the potential of gamification to appeal to a range of different users who are driven by different needs.

2.3 Gamification models and theories

The motivational theories presented in the previous section emphasize the point that SmartH2O requires an incentive model that offers different motivational affordances to account for the differences in needs and motivations of the users. SmartH2O has adopted a user-centered design process [8] to ensure that the user's needs and goals are the primary consideration at every stage of – in this case – a game design process. User centered design principles are necessary in such applications to avoid meaningless, or even harmful, gamification.
Nicholson [59] said that dependence upon extrinsic rewards for motivation should be replaced by links between the non-game activity and needs (or goals) in the user's life. The resulting user-centered gamification is expected to result in longer-term and deeper engagement between participants in non-game activities and supporting organizations.
First, there must be done a differentiation of player types, gameplay environment, emotional responses to gameplay, and the relationship between motivation and ability in games. In next sub-chapters, there will be a discussion of different theoretical models based on such differentiations. Those are important as a first step towards a gamified incentive model that is differentiated by user motivations.

2.3.1 Bartle's Player Categorization

Different players have various desires in games and their important factors of the game are different. Therefore, in order to create the right motivation for people to play game, there must be a deep understanding of the characteristics of various players. Bartle [10] categorizes players into four roles, which are:

- **Achievers:** players who want to gain points, levels, equipment and other concrete measures of success; they are competitive and enjoy beating difficult challenges whether they are set by the game or by themselves. The more challenging the goal, the more rewarded they tend to feel;
- **Explorers:** players who like to explore the world, not just its geography, but also the finer details of the game mechanics. These players may end up knowing how the game works and behave better than the game creators behave. They know all the mechanics, short-cuts, tricks, and glitches that exist in the game and work hard on discovering more;
- **Socializers:** players who are often more interested in having relations with the other players than playing the game itself. They help to spread knowledge and a human feel, and are often involved in the community aspect of the game (e.g., managing guilds or roleplaying);
- **Killers:** players who prefer to provoke and cause drama and impose them over other players according to game's possibilities.

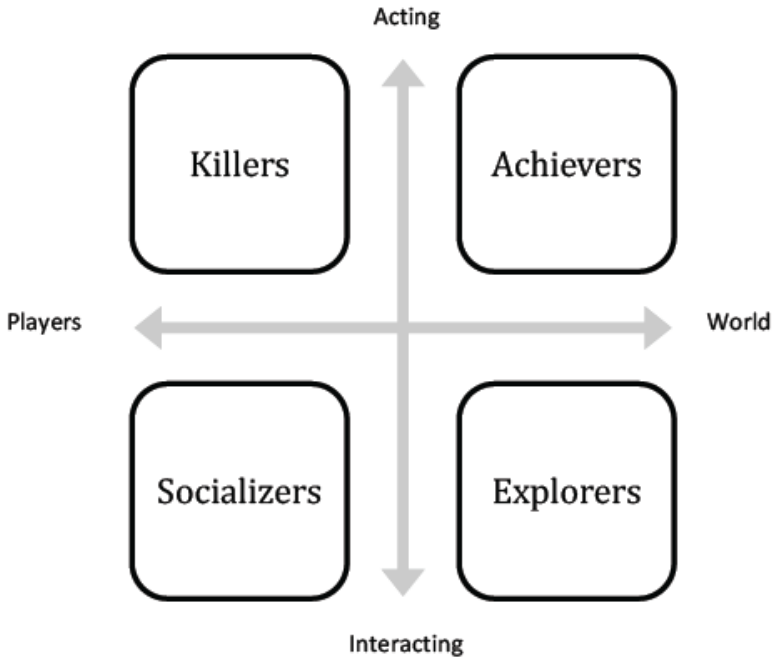

Figure 3: Bartle's player categorization

There are some players can have characteristics of all four types at the same time. However, most of them are not. If the scores were mutually exclusive (one player could only be one type), the vast majority of people would probably be socializers. Games like Farmville and Poker and their undisputed success are a proof of the above.

2.3.2 Kim's Social Engagement Verbs

Amy Jo Kim, a game designer, states that the key value of Bartle's system is to raise awareness that different people enjoy different types of fun [58]. She has developed a different point of view: "Social Engagement Verbs" that captures the motivational patterns seen in modern social gaming and social media. She gives another point of view to four types of players in Bartle's Framework [10]: **Compete**, **Collaborate**, **Explore**, and **Express**.
According to Kim [58], achievers are players who like to compete. However, it is just one of many motivators — and often not the best. Socializers, on the other hand, prefer to collaborate rather than to compete. Collaboration is driving many of today's most innovative and influential social systems and people who enjoy collaboration like to "win together" with others, and be part of something larger than themselves. Explorers are interested in exploring content, people, and tools. People who enjoy exploring are motivated by information, access and knowledge. For killers, Kim states that self-expression is a key driver for modern social gaming and social media, and is a major motivator for engagement and purchases. People who enjoy self-expression are motivated by greater abilities to highlight their creativity and express who they are.

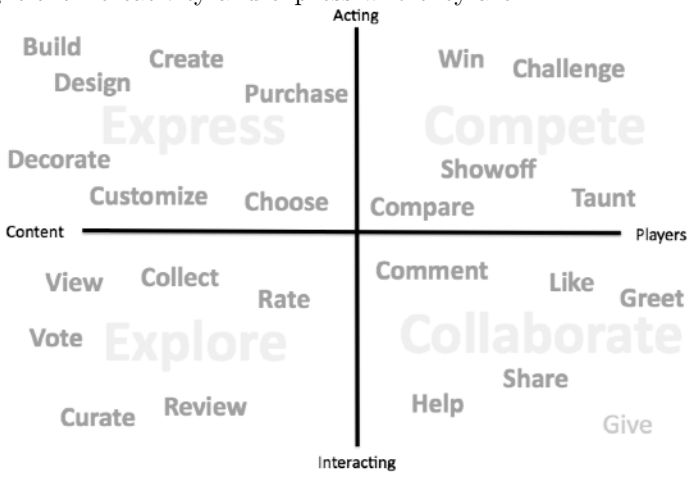

Figure 4: Kim's Social Engagement Verbs

2.3.3 Radoff's Gameplay Model

Jon Radoff uses two axes to define the environment the player: horizontal axis and vertical axis as shown in Figure 5 [54]. The horizontal axis describes the

number of players involved in an element of gameplay. The further one moves to the left the closer he goes to a single player. On the other hand, the more to the right, the more players he has. The vertical axis represents the measurement used to communicate to players whether they are 'winning' in the category of motivation: going upwards, things go from quantitative to more qualitative rewards. According to the two axes, the four quadrants model is proposed:

- **Immersion**: stories, roleplaying, exploration, imagination, and a sense of connectedness to the world of the game.
- **Achievement**: sense of progress, mastery of skills and knowledge, etc.
- **Cooperation**: player involvement in activities where they are helping each other, through creativity, shared adversity, etc.
- **Competition**: player involvement where individuals complete over scarce resources, comparison, and win/loss situations.

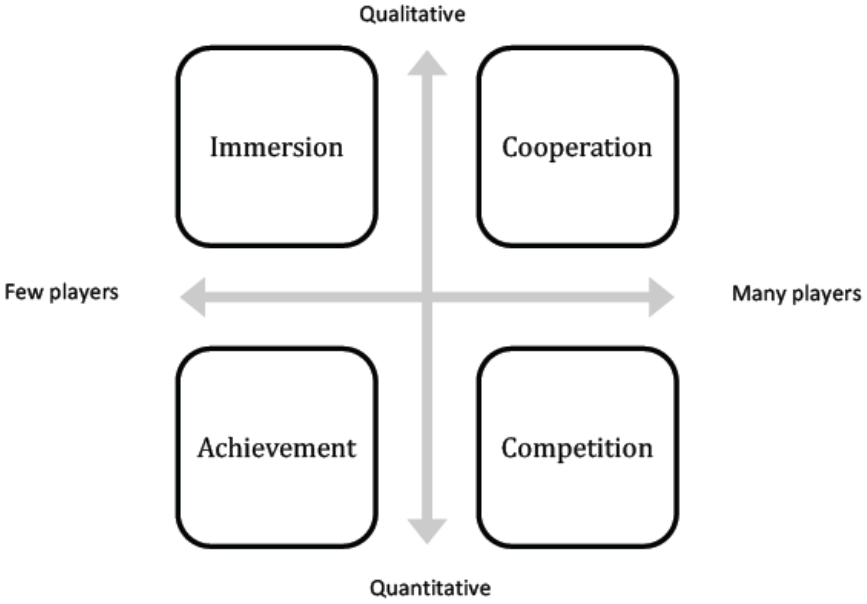

Figure 5: Radoff's gameplay model

2.3.4 Lazzaro's Player Emotion Model

In the research on the reason why we play games, Nicole Lazzaro mentions four key factors to the emotion of players while playing games [31]:

- **Hard Fun**: "Emotions from Meaningful Challenges, Strategies, and Puzzles" [31]. The challenge in the game focuses on attention and rewards progress for players, which creates emotion by structuring experience towards the pursuit of a goal. Feedback on progress are needed and success of players to inspire their creativity of strategies. There is also the need

to balance game difficulty with player skill through levels.

- **Easy Fun**: "Grabs attention with ambiguity, incompleteness, and detail" [31]. Easy fun maintains focusing on player attention rather than winning condition. Ambiguity, incompleteness, and detail combine to create a living world, which satisfies players' sense of curiosity, and they play the game to discover something new. The feeling of exploring and adventure is interesting to players.
- **Altered States:** "Generates emotion with perception, thought, behavior, and other people" [31]. These factors make players feel inside another world where they move from one state to another state to feel something different.
- **The people factor**: "Creates opportunities for player competition, cooperation, performance, and spectacle" [31]. This factor is important to players who play to spend time with other people, especially with their friends. Therefore, games are for social interaction and enjoyment comes from interaction with other people. Nicole Lazzaro points out that games that offer both cooperative and competitive modes, offer a wider variety of emotional experience and multiplayer games are the best at using people factor.

2.3.5 Fogg's Behavior Model

B. J. Fogg of Stanford University, an experimental psychologist, has demonstrated a strong parallel between incentive design and deploying game mechanics, by presenting the Fogg Model of Behavior (FBM) [42], a behavior model (see Figure 6).

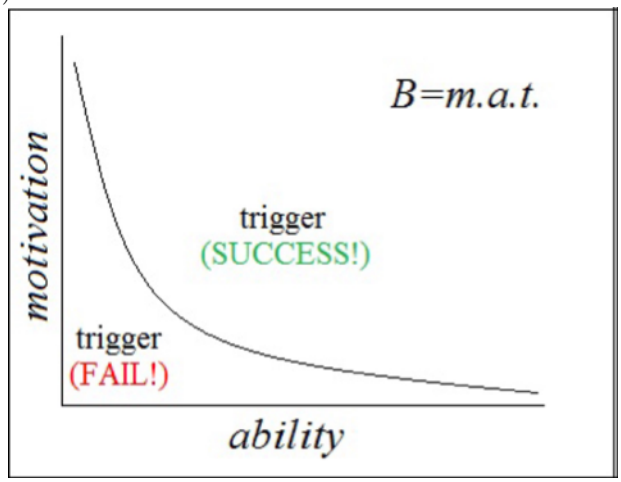

Figure 6: The Fogg Behavior Model

He says there are three factors underlying any human behavior: motivation, ability and triggers. For the behavior to happen, a person must have sufficient motivation, sufficient ability and an effective trigger, all of these being present

at the same time. The vertical axis is the motivation. It would be more difficult for a person situated low on the vertical axis to reach the target behavior. On the other hand, a person situated on the left side of the horizontal axis will have low ability to reach a target behavior. The trigger factor can be placed anywhere inside the plane defined by the motivation and ability, and can take many forms, as long as it "dictates" people to perform a behavior: from an alarm that sounds or a text message to an advertisement.

2.4 The SmartH2O approach to Behavioral Change

In SmartH2O, a systematic approach is followed to induce sustainable change in water consumption behavior that is grounded in motivational theory and research on incentive models. In next sub-chapters, there will be a broader outlook on the behavioral change process, which also considers the steps necessary after incentivizing users to retain their attention and engagement, done to maximize the effectiveness of the social awareness application. In [64] there is the definition of Behavioral change support system (BCSS): "...a socio-technical information system with psychological and behavioral outcomes designed to form, alter or reinforce attitudes, behaviors or an act of complying without using coercion or deception". The application should be perceived as such a BCSS, and then it must be based on the assumption that a change in water consumption behavior only occurs when underlying psychological determinants are changed through a combination of different incentive and persuasion strategies. *How* these determinants and ultimately water consumption can be changed? In this section there will be, first, the research of the determinants, followed by the behavioral change process (e.g. the 'how'), and finally the outline of the development approach for the SmartH2O social awareness app, as the implementation of the SmartH2O behavioral change strategy.

2.4.1 Determinants of water consumption

Research has shown that water consumption behavior is affected by a multitude of psychological, demographic, climatological, and economic factors. While all classes of factors affect water consumption, demographic and climatological factors cannot be changed through a BCSS. The social awareness app therefore focuses on influencing the psychological factors – referred to as "determinants". Ajzen [9] has introduced and validated the *Theory of Planned Behavior* (TPB) that models the relationship between attitudes, intention, and the target behavior (i.e. water consumption). This model has been the basis for a longstanding line of research, as well as the design of interventions in various domains of practice. The TPB model is depicted in Figure 7.

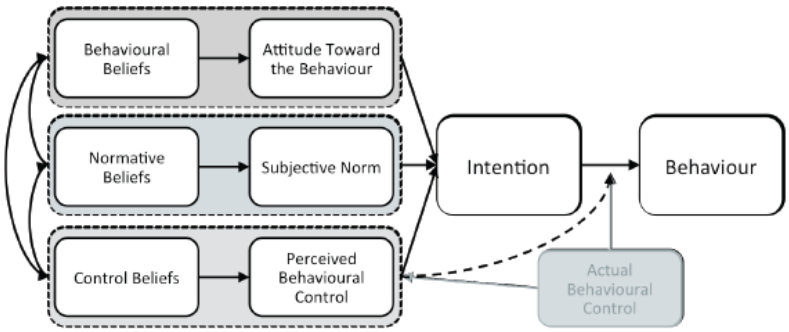

Figure 7: Theory of Planned Behavior [9]

The core constructs of the TPB model are:

- **Behavioral beliefs**: an individual's subjective estimation of the probability that a behavior will have certain consequences.
- **Attitude**: an individual's positive or negative evaluation of self-performance of the particular behavior.
- **Normative beliefs**: the perceived behavioral expectations of important referent individuals or groups.
- **Subjective norm**: perceived social pressure to engage or not to engage in a particular behavior.
- **Control beliefs**: the individual's perception of the factors that facilitate or impede the performance of a particular behavior.
- **Perceived behavioral control**: an individual's perception of the ability to perform a particular behavior.
- **Actual behavioral control**: the extent to which a person has the skills, resources, and other prerequisites needed to perform a given behavior.
- **Intention**: an individual's readiness to perform a particular behavior.

Whereas this model has been applied in many different settings, it cannot adequately explain habitual behaviors. Habits are automatic behavioral tendencies that arise because of repetition and practice of actions in similar situations [13]. Habits become stronger when the frequency with which the behavior is performed increases. This is the case in water consumption: a large share of consuming water at home or in the garden is both occurring frequently and habitual.

Then, the TPB model explains behavior based on the specific beliefs and attitudes towards the targeted behavior (e.g. the attitude towards turning off the tap while brushing your teeth over the duration of the next month). Lessons from environmental psychology suggest that also beliefs that are more general and attitudes towards the environment affect behavior [24, 55, 61].

TPB-based research often suffers from the so-called 'attitude-behavior'-gap, which refers, on the one hand, to the discrepancy between attitudes and resulting behavioral intention, and on the other hand the target behavior, suggesting that the model does not capture all relevant factors that affect the behavior.

Then, it has been seen that the hedonic values of an individual (comfort levels and feelings) have a negative affect both environmental attitudes and environmental behaviors [73]. Therefore, a successful behavioral change strategy for water consumption must refine the attitude concept in the TPB model to include these general environmental beliefs and attitudes, and hedonic values.
Different attempts have been made at developing a more comprehensive model, contextual to water consumption behavior. Jorgensen et al. [**Jor091**] made a review about social and econometric models. That review pointed out that existing models suffer from low explained statistical variances and that a new model is needed to comprehensively cover psychological, social, and economic factors. Their new integrated model combines these factors, with the TPB model at its core. This new model includes specific attitudes towards water consumption restrictions, water pricing, and water conservation, while incorporating acknowledges about the habitual nature of water consumption. Finally, socioeconomic, demographic characteristics, and climate/seasonal factors are introduced as drivers of water consumption.
In SmartH2O, the continuous (gamified) incentive of users throughout the behavioral change process is at the center of the attention. However, in the model described above – and in water efficiency research in general – the motivation of users to expose themselves to information about water and subsequently to engage in water saving actions has not been addressed.
Finally, this model offers a static view on behavioral change. In the next subsection an alternative perspective is proposed, saying that the behavioral change process in SmartH2O should be considered as a *multistage process*.
Phases in the behavioral change process are:

- **Pre-contemplation**: People are unaware of the need for behavioral change, and have no intention to change their behavior in the next six months. People overestimate the disadvantages of the behavior, and underestimate the advantages. The "seed must be planted" to acknowledge problematic water consumption behavior.
- **Contemplation**: People are aware of the need for change, and intend to act within the next six months. However, they equally weigh the pros and cons, which can result in postponing the behavior. The tip of the balance must be moved in favor of change.
- **Action**: People start taking small steps by employing the first actions. People need to prevent themselves from slipping back, requiring continuous reinforcements (positively reinforce sustainable water consumption).
- **Maintenance**: Even though people in this phase have changed their behavior more than six months ago, they need to gain awareness of situations that may tempt them to slip back to the old behavior. There must be the development of intrinsic motivations for saving water.

2.4.2 Pre-contemplation: preparing the ground

The first step is to raise awareness about problematic behavior: users consume too much water. The SmartH2O system uses different strategies:

- *Habitual nature of water consumption*: as has been said before, habits have a strong influence on water consumption behavior [**Jor091**, 56]. Appealing to the user's general needs and desires, as outlined in Section 2, users need to be incentivized and their awareness about water consumption needs to be raised. Bringing water consumption behavior to their explicit attention is a fundamental step.
- *Unclear consequences*: disadvantages of consuming more water than needed are not immediately visible to the user. In this phase, it is then important to make users more aware of the consequences of their behavior, and demonstrate what they can do by themselves to change or avoid the negative consequences, following Schwarzer's model [12].
- *Balancing goals*: Goal framing theory [36] suggests that for an individual user, three types of goals are active at the same time: hedonic goals, gain goals, and normative goals. The first leads people to focus on ways to improve their feelings in a particular situation. Gain goals let people be particular sensitive to changes in their personal resources, such as money and status. Normative goals lead people to focus on the appropriateness of actions and make them especially sensitive to what they think they ought to do.
- *Unclear social norms*: there are two kinds of norms: Descriptive norms refer to an individual's beliefs about the prevalence of certain behavior within a group. Injunctive norms refer to an individual's beliefs about the extent to which others within the group would socially approve of us if we engaged in a particular behavior [72]. Social norm-based feedback should ideally combine both types of norms into a single message.

2.4.3 Contemplation: going towards water saving

In the contemplation phase, users actively think about their water consumption behavior. Strategies should be aimed at tipping the balance towards favorable attitudes on saving water. In this phase the lack of knowledge about how much water users consume must be handled. Then, people may question what they could actually do to save water. Randolph and Troy [40] also said that the extent to which people believed that they could do more to save water was unrelated to their actual level of consumption. These results suggest that in this contemplation phase specific water saving tips are needed to tip the balance towards more favorable attitudes on water consumption. From the goal perspective [36], it's important to emphasize that hedonic values are not impacted by water saving actions, or that personal gains can be achieved in exchange for a slight reduction of comfort (e.g. by reducing shower time by one minute).

2.4.4 Action: strengthen positive behavior

In this phase, users start putting the target behavior into practice and information on how users can change their water consumption behavior needs to be provided. This time water saving tips are directly aimed at supporting users in

their new behavior. This phase requires positive reinforcements to secure the acquired behavior as a new habit, provided that the user has been incentivized to question the old behavior and to think about its negative consequences [11]. The BCSS should also strengthen the commitment users have towards the new water saving behavior. Social sharing of positive outcomes, and setting goals in a way that is visible to significant others could increase commitment.

2.4.5 Monitoring: Develop intrinsic motivation and reinforce sustainable water consumption

Only when users are intrinsically motivated to save water, a sustainable change in behavior occurs. That is, according to self-determination theory, people will be motivated to save water when it can increase their perceived level of competence, their psychological affiliation to others, or their sense of autonomy [19], as opposed to extrinsic motivation, such as (monetary) rewards. The cyclical loop of intrinsic motivation must be maintained: interest, curiosity, optimal challenge, competence feedback and enjoyment [47].

2.5 From theory to concrete strategies

In subchapter 2.4, the theoretical foundation has been provided for the multistage behavioral change strategy that has been adopted in the SmartH2O to engage users, and subsequently to change their water consumption behavior. But several problems have been found in current research: the habitual nature of water consumption, the well-known attitude-behavior gap, and the dissipation of positive effects over time.
SmartH2O social awareness app manages behavioral change as a multistage process, with different phases requiring different strategies. It offers incentives and feedback to users in all phases of the behavioral change process. Then, based on the review of motivational theories and gamification models in past sections, a gamification part has been introduced as a solution to initiate and sustain the behavioral change process.
The analysis of motivational theories, the modelling of the behavioral change theories, and the positioning of gamification within the behavioral change process together provide the foundation for the definition of the SmartH2O incentive model.
In the end, it has demonstrated that users differ in terms of the motivational affordances they are sensitive to. These differences users imposed some design choices of the incentive model, requiring a model that can engage all users regardless the motivational affordances that can engage them. The resulting incentive model, following De Young [16], utilizes antecedent strategies, that refers to the ones that influence the determinants of behavior before the behavior occurs, and consequence strategies, that influence such determinants after the user behave. Those consequences are linked to the outcome of the behavior. Then, both the web portal and the mobile version of SmartH2O implement the following functionalities:

- **Interactive exploration of water consumption data:** being aware of how much the user is consuming is a first step in the improvement of consciousness regarding the water wasting problem. In addition, interface design influences hedonic quality, which is in turn linked to both engagement and task performance [**Mel15**, 44]. It appeals to the user's need for achievement (need achievement theory, [4] see 2.2.1) in the sense that a well-visualized decrease of water consumption levels augments the user's feeling of accomplishment, as well as the user's feeling of autonomy [7]. Furthermore, by comparing their consumption to the nationhood's average, the change in behavior could rely on users' normative goals of the desire to act appropriately. Colors are also important to give a injunctive normative message to the users: the green, orange or red light on top of the consumption pipe that all highlight the behavior that is expected from the user, and remind people of their past water behavior.
- **Incentives through physical, social and gamified virtual rewards (points and badges)**: users need to be incentivized to be actively involved with water, then positive behavior should be reinforced, due to the fact that the effect achieved can diminish over time [56]. That's perfectly in line with Skinner's reinforcement theory (2.2.3) that stands the importance of continuously reinforce the motivation of users over time [3]. The user's hedonic goals have shown to be important determinants for environmental behavior such as water consumption [36, 73], but the contribution to such goals can also help to bootstrap the behavioral change process in itself. In SmartH2O the user's hedonic goals are anticipated by means of gamification, the use of game design elements in non-game contexts [49]. First users must be extrinsically motivated, then, once internalized the new behavior, intrinsically motivated with new habits.
  Moreover, the combination of virtual and physical rewards is necessary due to the different level of playfulness of the users. The promise of physical rewards at the start of using the platform is important especially to users who do not feel motivated by gameplay alone to engage in water saving actions on the platform they can get points for.
  In the end, the combination of a leaderboard section in conjunction to physical rewards that could be won depending on the weekly and monthly ranking in such a board, draws on those users' motivations: basic desires of competition and collection (section 2.2.1), opportunity of social comparison [2] and continuous reinforcement of positive behavior.
- **Setting water consumption goals**: are expected to create commitment towards the target behavior. Not fulfilling them can cause cognitive dissonance, whereas achievement is expected to strengthen hedonic, normative and gain goals of the user [36]. It's also connected to gamification: achieving goals led to gain points, which result in social recognition in leaderboard. This will increase intrinsic motivation leading to forming new habits [7, 11]. Demonstrating how much a user can save results in increased awareness of the consequences, a reduced denial of responsibility, a higher efficacy, and a higher situational responsibility. Finally,

according to need achievement theory [4], and individual's self-perception is improved when he experiences the success of achieving goals.

- **Competing against others**: the leaderboard section with overall and weekly high scores, highlighting the water saving performance of the top users, encourages not only competition, but also opens up the opportunity to enhance the user's self-perception. According to social comparison theory , people seek to evaluate and/or seek to get more positive beliefs about their own abilities by comparing themselves to others.
- **Actionable water saving tips**: this part has two objectives. Increasing the perceived behavioral control and encouraging social learning. According to the theory of planned behavior [9] and to self-efficacy theory (section 2.2.1, [5]), the extent to which a user is confident that he can actually perform the desired behavior affects the user's behavioral intention, and subsequently the behavior itself. As has been said, the theory postulates that people acquire new behavior through observation, imitation, and modelling. The new behavior has the maximal chance to be adopted if the following conditions are met: the subject must pay attention, must be able to store and/or retrieve examples of behavior, must be able to practice the behavior, and most importantly must be motivated to perform the behavior. Tips are the best way to constantly provide the user the best information on how water can be saved. Reading tips can lead to gain points and, then, rewards.

3 The SmartH20 technical architecture

In this constructed network, users could see good and bad practices of others and exchange tips on how to improve consumption. The other goal is to test different water demand management strategies and identify which of these strategies were most effective. The goal here is to encourage weighted consumption during off-peak times (e.g. washing machine outside of peak showering times) and during wetter seasons [67].
From the technical viewpoint, building the SmartH2O system is a challenge due to several factors stemming from the hybrid nature of the solution to be constructed. In this chapter there will be made an overview on the architecture and the main modules of the platforms, the objectives and motivations that has led to such an architecture and the main components of the SmartH2O social awareness app.

3.1 Synthesis of requirements

In the following subsection, there is the final outcome of the requirements analysis, which consisted of literature studies and target user group analysis (detailed in further sections), updates from recent studies on water consumption reduction, lessons learnt from gamified energy conservation systems, and additional feedback from water consumers and the wider innovation community of the SmartH2O project [76], not treated in this thesis.
Below, a list of the major requirements is present with associated one or more components of the SmartH2O platform build to fulfill each of them [76]. In next subchapter there will be a detailed description of such components mentioned below.

- **Basic customer portal: Visual water meter**
  - Collecting consumption data (with smart meters / manually), visual exploration of water consumption information (also at fixture/appliance level) and feedback on disaggregated consumption data:
    * Portal Exchange Data Manager
    * Basic Customer Portal
    * User and Consumption Database
    * ESB
  - Informative part: getting water consumption alerts, tips, system notifications and earning interactively about innovative pricing schemes:
    * Business Dashboard
    * Basic Customer Portal
    * User and Consumption Database
    * ESB
- **Advanced customer portal: Gamified water meter**
  - Making gamification actions and exploring results, such as: setting consumption goals, fulfilling consumption goals, declaring water saving actions, contributing household and user profiling, declaring wa-

ter end-use events, verify manually inserted consumption, making actions and earning digital credits with the Games Platform.
    * Advanced Customer Portal
    * Gamification Engine
  - Recommending water saving actions:
    * Advanced Customer Portal
    * Gamification Engine
    * Customer Portal Admin
- **Advanced Customer Portal: Social water meter**
  - All the social and community actions: comparing achievements with other households, inviting others to join a team, achieving goals collaborating as a team:
    * Advanced Customer Portal
    * ESB
    * Gamification Engine
  - Interaction with social networks: inviting friends and sharing achievements on social networks:
    * Advanced Customer Portal
    * ESB
    * Gamification Engine
    * Social Connector
- **Customer portal user account management**
  - User management and authentication:
    * Customer portal sign-up: Basic Customer Portal
    * Gamification Engine sign-up: Advanced Customer Portal
    * Modifying users' settings: Advanced Customer Portal
    * Upgrading to advanced/downgrading to basic portal: Basic/Advanced Customer Portal
    * Leaderboard opt-in/opt-out: Advanced Customer Portal
    * Geolocation opt-in/opt-out: Advanced Customer Portal
    * Customer Portal Un-subscription: Basic/Advanced Customer Portal
- **Customer Portal Admin**
  - Set-up requirements: setting water consumption tips, actions, badges and rewards and converting game actions into rewards
- **Games Platform**
  - Player management: sign-up, playing standard mobile game, playing mobile game in addition to the board game. Then, player profile must be connected to the Gamification Engine and there must be the possibility to set the content of game's questions.
- **Business dashboard: Customer consumption monitor**
  - Visualizing aggregate household consumption information by geolocation
  - Querying and displaying customer attributes
  - Identifying customer groups
  - Setting consumption goals and rewards for specific customer groups

  - Setting recommended water saving actions for specific customer groups
  - Setting water consumption alerts
    * Business Dashboard
    * ESB
    * User and Consumption Database
- **Agent-based Customer Consumption Simulator**
  - Modelling behavior based on consumption
  - Predicting customer segment consumption behavior
  - Predicting behavior based on incentive response
  - Predicting customer segment response to pricing schemes

3.2 User roles

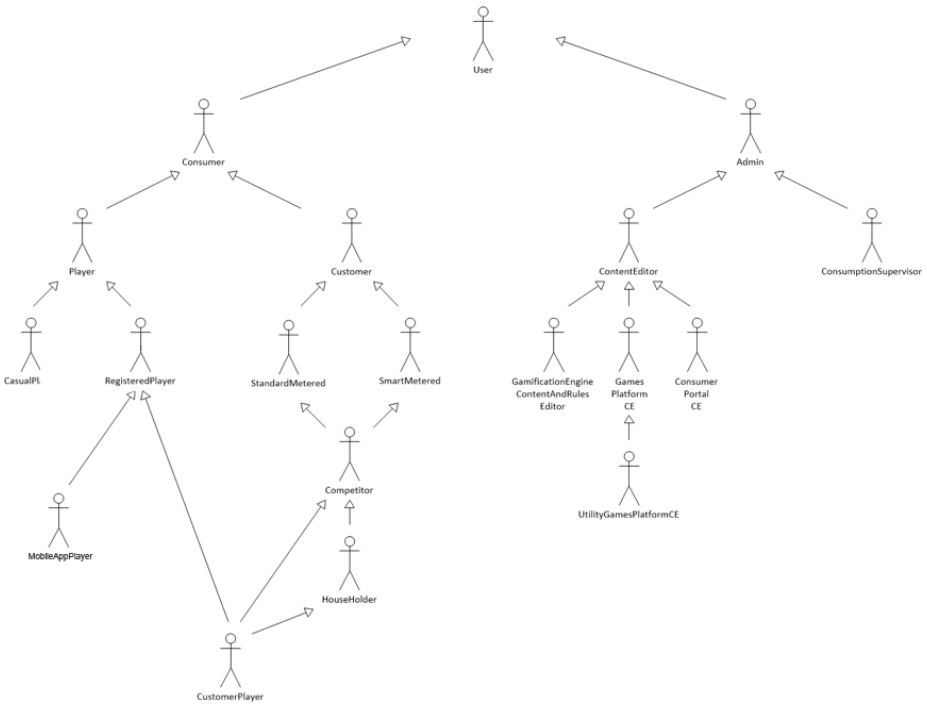

Figure 8: Users model

The target users of the smartH2O platform can be divided into different groups and should be considered separately for the three case studies in the UK, Switzerland and Spain [76].

- **UK case study user groups**:
  - Water consumers in domestic households in Greater London, with a focus on the smart meter rollout sites in Reading (155'300 inhabitants) and Swindon (185'609 inhabitants).
  - Water utility staff in Greater London (Thames Water).

- **Swiss case study user groups**:
  - Water consumers in domestic households in Southern Switzerland in the Locarno region (Canton of Ticino), with a focus on the smart meter rollout sites in Tegna (800 inhabitants) and Tenero-Contra (2'700 inhabitants; in total ~600 households will be equipped with smart meters).
  - Electric utility staff in Southern Switzerland (SES).
  - Municipal administrators in Southern Switzerland.
- **Spain, Valencia EMIVASA case study user groups:**
  - *Aguas de Valencia* started to install smart meters 9 years ago, and by the end of 2015, 650'000 smart meters are supposed to be in place. Claiming to be the "most advanced company in Europe in terms of smart metering", their main objectives for applying smart metering are more accurate water balances and faster leak detection. They are using seven different smart metering technologies from different vendors, which are integrated using a common data format and platform [74].
  - Not all smart meters used provide hourly readings, but for the project they will ensure hourly samples are available for all participating households.
  - *EMIVASA Virtual office*: The Virtual Office is the online customer service portal of the *Aguas de Valencia*'s group. It currently counts around 60'000 users.

A first distinction among user groups must be done according to the use that they can do of the application. Two main groups, then, can be found: **Consumer** and **Admin**. The former is the generic user who can access the services provided by the SmartH2O system; the latter is instead in charge of managing the services provided by the SmartH2O system.

- **Admin** (Water utilities and regulators): policy makers such as water utilities and regulators at national and EU level. For them the benefits are manifold:
  - Reduction of water consumption
  - Monitor of water usage
  - Improvement of business operations
  - Improvement of resource efficiency
  - Increase in efficiency in communication.

  They are partitioned into sub-groups based on which services they manage:
  - **Content Editors** are administrators in charge of creating the content of the applications composing the smart water system.
    * *Gamification Engine Content and Rules Editors*: they are in charge of creating the content related to the gamification platform (the one used by Competitor users) such as actions, rewards and goals. They are also in charge of defining the rules to assign the suitable amount of points to each action.
    * *Consumer Portal Content Editors*: they are in charge of creating the content related to the platform used by Customer users, such

as tips to improve water saving, teaching videos.
    * *Games Platform Content Editors*: they are in charge of creating the content related to the games, such as the questions provided in a quiz game related to generic water consumption topics.
    * *Utility Games Platform Content Editor*: they are a specialization of the Games Content Editor users, related to a specific utility game. For example they manage the specific questions provided in a quiz game.
  - **Supervisor**: are administrators in charge of monitoring and managing system data. They can be:
    * *Consumption Supervisor*: they are in charge of modelling users consumption.
    * *Gamification Engine Supervisor*: they are in charge of profiling users, making available users clusters that can be used to suggest the most suitable actions to perform.
- **Consumers**: they are the users of the water utilities at local/regional or national level. They can be single, coupled, shared (typically younger residents) households or family households with older children (teenagers). For them benefits are:
  - Reduction of water consumption
  - Monitor of water usage
  - Education and change of behavior

  They are partitioned into sub-groups based on which services they access:
  - **Player**: users are the ones who play the Games provided by the SmartH2O system. They can be:
    * *Casual Players*: they are not registered visitors interested in playing a game.
    * *Registered Players*: they are registered to the Games platform.
  - **Customer**: are users registered to the Consumer Portal, who access in order to monitor their water consumption and water bill. They can be:
    * *Smart metered users*: they are customers having smart meters system installed in their house. The water meter measures the customer's water consumption automatically.
    * *Standard metered users*: they are customers not having smart meters system installed in their house. They need to manually input consumption data into the gamification engine.
  - **Competitor users**: they are the ones who accepted to participate to the gamification mechanisms, including execution of actions, acquisition of badges and redemption of rewards.
  - **House holder user**: he/she is the responsible of a specific house. He/She can add other family members to the Gamification Engine and create collaborations with neighbors.
    * **Customer-Players**: are users who are registered both to the Gamification Engine and the Games Platform. They have the possibility to collect points either by performing actions provided

in the gamification engine or by playing the available games.

3.3 Overview of the architecture

The original concept of the SmartH2O architecture indicates the components and the processes that will be implemented in order to achieve individual and collective behavioral response to specific water conservation policies [70].

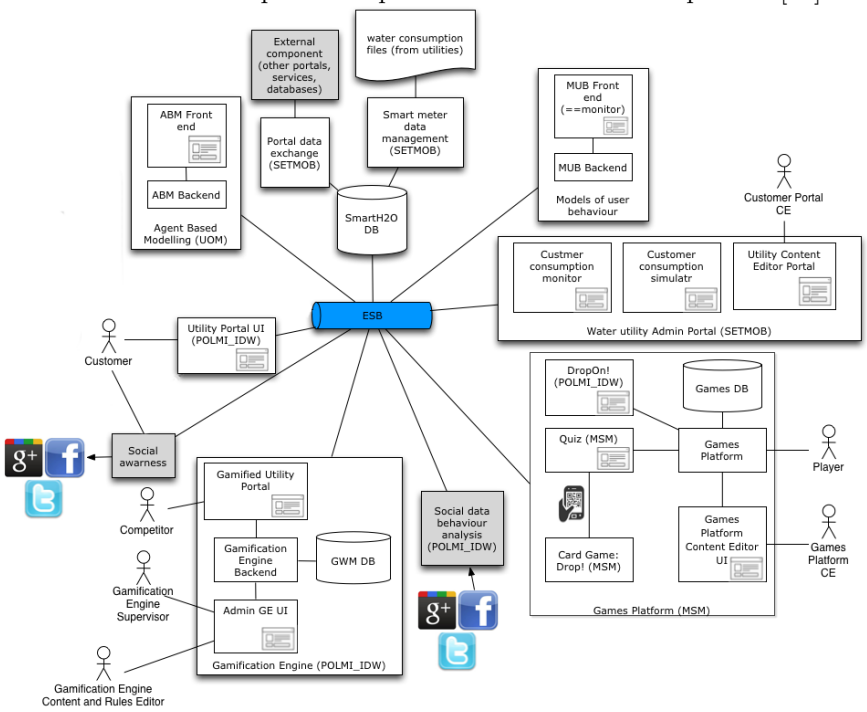

Figure 9: SmartH2O Architecture

Seen as a system, SmartH2O platform can be seen as a *negative feedback control system.*

A negative feedback control is specific to a system in which the output of the main process related to a proposed objective is fed back into the input with the purpose to reduce the effect of increasing the input. This kind of feedback control generally induces stability over a proposed objective [67]. In this case, the purpose is a sustainable water conservation policy, the negative control feedback is inducing a shared understanding and motivation in the water users, leading to a reduction of the water consumption avoiding a decrease of the quality of life.

According its social objectives described in the previous chapters, SmartH2O platform's architecture is designed with respect to the main data flows:

- **Input flow**: user behavioral data (usage metering, social game and social media profile)

- **Control flow**: social game incentives and price signals. This flow is supposed to trigger changes in user behavior according to Water Supplier objectives

In addition, the platform must also deal with water utility subscriber profile data coming from Water Supplier portals and reporting analysis tools for Water Supplier companies.
To summarize: SmartH2O Platform relies on **collecting data** from water utilities, end-consumers gaming actions and social media, **processing data** using data analysis instruments such as gamification, agent based modelling and price modelling, then **measuring and exposing** user behavior changes.
Specific independent (from vendor product or technology) components must be identified, and also their role in the architecture. This lead to the decision of implementing a *Service-Oriented Architecture* for SmartH2O.
Technical implementation of SmartH2O Platform is based on a layered architecture. Each layer was designed with respect to separation of concerns principles. The architecture, then, relies on four different layers [70]:

- **Data acquisition layer**: responsible with bulk data acquisition and delivery.
  Inputs:
  - Raw water usage data files from Water Utilities
  - Social media user data
  - Other REST based data sources, user portals of Water Utilities

  This layer can be seen as a mediator component that handles raw data acquisition, transformation and storage in a format that can be used by upper layers.
- **Data/Object layer**: responsible for data storage in SQL (noSQL where needed). Exposes services to upper levels for basic access data. Data stored are:
  - Water usage data
  - User profile data
  - Game actions and rewards data
  - Social media data
  - Agent based modelling data
  - Price modelling data
- **Business Process layer**: responsible for implementing the business logic. It will expose business services for Consumer layer. Its components are:
  - Gamification Engine: provide game scenarios and handle user interaction with the platform through social game clients (see section 3.7).
  - Pricing Engine: will implement econometric modelling of urban and industrial price response, without social media intervention, of a dynamic link to water supply or environmental conditions. Implemented through its own API.
  - Agent-Based Modelling (ABM) engine: will be implemented in an agent-based simulation platform. Integrated through its own API.
- **Consumer layer**: consists of client applications for services exposed by the Business Process Layer. Consumer of platform business services are:

– GWAP (Game with a purpose) client application
– Modelling client applications
– Platform administration and configuration application
– Water Utility subscriber application

3.4 Description of modules

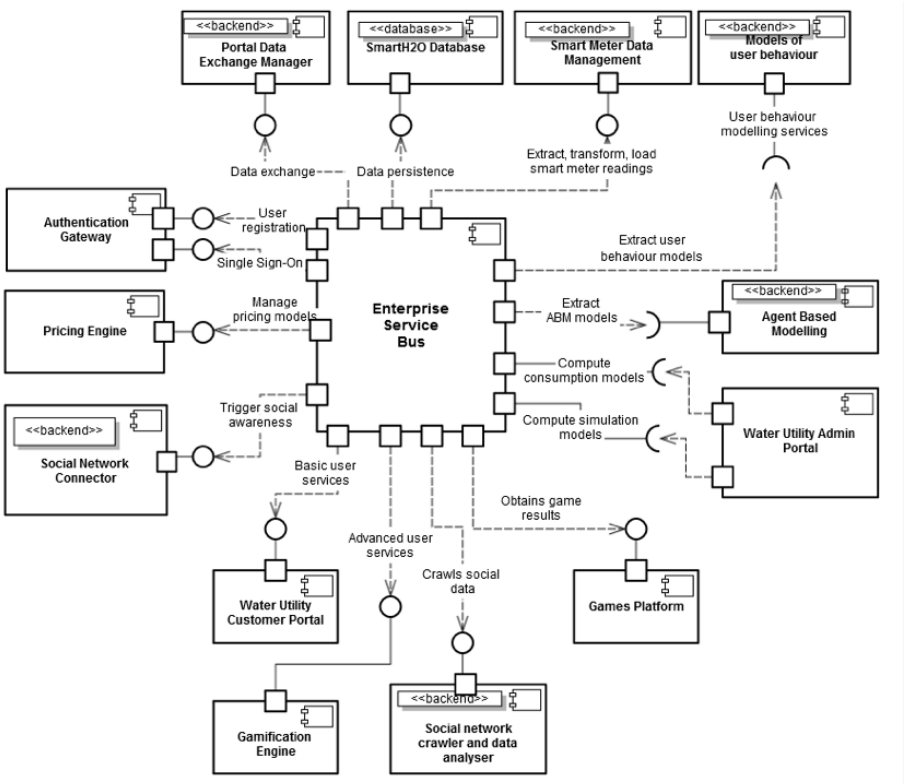

Figure 10: Overview of the main components of the SmartH2O architecture

In this subsection there will be made an overview on the main components of the SmartH2O architecture, as can be seen by Figure 10 [71].
The **SmartH2O Database** is the central repository of the information that is common to all the SmartH2O components and supports the coordination and exchange of messages among them. Commercial data about the water consumers is not present, but is maintained by the water utility and stored in the proprietary system of the company.
The **Smart Meter Data Manager** is in charge of the acquisition of data streams from smart meters and of their consolidation within the SmartH2O database. It implements the data privacy and security policy of the utility company and ensures that only admissible data is stored within the platform database.

The **Enterprise Service Bus** (**ESB**) is a middleware layer that supports the loose coupling of the SmartH2O components; it permits the publication of their interfaces (Application Programming Interfaces, APIs) and the synchronous and asynchronous communication among components. It is important for decoupling heterogeneous components present in SmartH2O architecture as much as possible, permitting future extensions with new services and functions.
The **Water Utility Consumer Portal** is a component, embedded within the proprietary portal services of the utility company, which supports the interaction between the utility customers and the SmartH2O awareness functionality. The navigation is from the standard GUI of the utility portal toward a special section of the portal, where the user can access to all the tools and interfaces developed by SmartH2O. Further information will be present in section 3.5.
The **Water Utility Admin Portal** is a component, embedded within the proprietary portal services of the utility company, which supports the work of the supervisor in the analysis of the water consumption data and of the outcome of the gamification rules; it also supports the work of the content editor, who administers the content (e.g., tips, articles, news, etc.) published on the platform. Further information will be present in section 3.6.
The **Portal Data Exchange Manager** deals with the data exchange communication that occurs "behind the scenes" among the SmartH2O platform and the third party applications. Such applications may be the "standard" customers' portal of the utility company, or a B2E application for the utility company's supervisors.
The **Gamification Engine** is a back-end component exploited in order to "gamify" the water consumption of the users, according to the awareness approach implemented by SmartH2O (see Chapter 2). It embodies rules for transforming users' actions into gamification scores and achievements. It has an interface for the end-user, who sees the results of his/her water consumption actions; and administrative interfaces for the utility company's managers and operators, who can monitor the outcome of the awareness-raising policies and define the rules that reward the actions of water consumers. Further information will be present in section 3.7.
The **Games Platform** supports the execution of all the digital games of SmartH2O, including the games that are played as part of the interaction with the Drop! board game (further information will be present in section 3.8). The Games Platform need to support casual players, and thus has both an independent users' registration procedure and a procedure for enrolling users that are already registered in the Utility Portal. It has two interfaces: one for "standard" users, one for administrators.
The **Pricing Engine** allows water utility companies to weight the different dynamic pricing algorithms according to their customer behavior. The pricing engine will use consumption data, user profile data, external input like meteorological data and water supply forecast.
The **Models of User Behavior** component is used to identify the relevant features to be used in classification and has models and algorithms to profile water consumers. It contains a classification algorithm that creates user seg-

ments (classes of users with similar behavior) on the basis of their features. It also contains a disaggregation algorithm that can attribute the end uses of the total amount of water used by a household during one day, with a certain degree of approximation. This component is useful to study the users' behavior and to collect consumption patterns and trends.
The **Agent Based Modelling** component allows the simulation, by the water utility, of the whole districts of users, extrapolating user models provided by the Models of User Behavior component at a larger scale and also the impact of network effects due to users' interactions, both in the physical and in the virtual world.
The **Authentication Gateway** component centralizes user registration into the SmartH2O platform database for the users registered in components having own user database. It gives a unique point of authentication to all users.
The **Social Network Crawler and Data Analyzer** component allows the platform, where deemed appropriate by the water utility portal, to launch social data analysis campaigns to identify relevant users and content in the area of sustainable water consumption.
The **Social Network Connector** component allows Consumer, Player, and Competitor users to post their achievements from the SmartH2O Water Utility Portal and Games Platform to the social network of their preference, in order to engage people to the water consumption and sustainability campaigns of the water utility company. It plays a dual role w.r.t. the Social Network Crawler and Data Analyzer.

3.5 The Consumer Portal

The smartH2O customer portal let customers to access to their water consumption information. It will be available as a basic version that focuses on the basic water meter access, and an advanced version implementing the gamified platform, which enables interactive water saving and raises customers' individual awareness of their consumption and their social awareness by enabling them to compare themselves directly with others.
Basic Portal with following use cases:

- Visualization and exploration of consumption data.
- Provide feedback on disaggregated data.
- Receive notification, water saving tips and alerts.

Advanced Portal which adds to Basic Version the Gamification and Social use cases:

- Set consumption goals, explore results, earn points, get badges, awards and physical rewards.
- Declare profiling information and end-use water events.
- Compare achievements with other participants.
- Join teams, play as a team and invite others to join a team.
- Interact on social networks by sharing results and inviting friends from social network to join the Platform.
- A mobile trivia game

  - Play trivia Game on water saving topics and earn points that can be added to its Advanced Portal account.

The main sections of the Customer Portal are:

- **Consumption and Goals (advanced portal) sections**: provide customers with their consumption information. Water consumption is displayed on two tabs. On the first tab, the user's water consumption is displayed as bar charts. Optionally, users can display a line in the bar charts that display the average consumption level of their neighborhood. Bars can be displayed to represent a day, a week, or a month.
  On the second tab, a visualization is shown that visualizes water consumption in a pipe that is to some extent filled with water, with higher water levels representing higher consumption. Baseline values – computed based on historical average water consumption for the user – are depicted with a dashed line in the water pipe. Users, in the advanced and gamified version of the portal, are encouraged to engage in water saving by displaying water saving levels of 5%, 10% and 15% respectively.
- **Reward section**: In the gamified version of the platform, users can gain points and badges for doing actions on the portal. Actions are manifold: users can get points for logging in, setting goals, reading tips, watching videos and filling out their user profile. Users are also awarded for validation activities, such as filling out a questionnaire.
  These points are counted in total, but are also attributed to four different thematic areas: *water saving actions* (reducing consumption), *water saving insights* (e.g. readings tips and watching videos, correctly answering Drop! water trivia questions), *profiling actions* (proving details about one's household or devices), and *participation actions* (social sharing features, leaderboard achievements). In the status bar, a summary of the user's status is present.
  Users can win physical rewards: earning points will led the user to receive a gift. That will incentivize a customer to do actions on the portal (and to save water). Two different kind of approaches has been pursued due to the two different context in which the portal will be used: Spanish and Switzerland cases.
- **Leaderboard section**: contains both overall and last week's high scores, highlighting the performance of the users. The leaderboard displays the points and badges the top-n users have been collected. Two leaderboards are presented: the 7 days' leaderboard, and the overall ranking. Both display the top users with the number of points and their badges. The user's own position is highlighted.
- **Tips section**: in the SmartH2O social awareness app, attention to the water saving tips is drawn both from the menu bar and from the status bar. Users can browse through a series of tips about a variety of topics and places around the house and garden in which water consumption reductions can be achieved. Furthermore, videos are offered that highlight potentially water saving actions in a visual way.

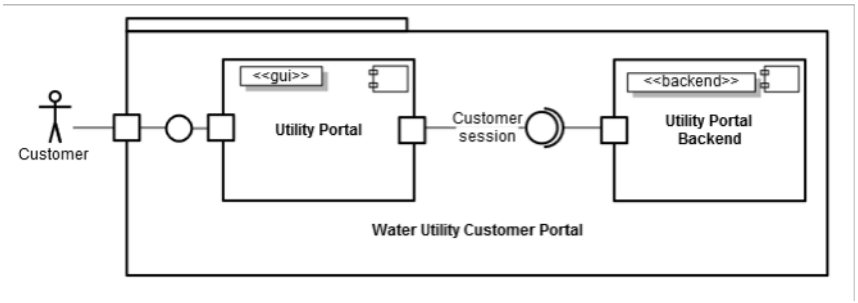

Figure 11: Customer Portal Component Diagram

3.6 The Admin Portal

The Admin branch of user roles will interact with the Platform via specialized content editors for each component [71]:

- Basic Portal: water saving tips, videos and info.
- Advanced Portal: game rules, badges, awards, physical rewards, point redeeming rules
- Mobile Game: trivia questions and points awarded.

The portal offers services to the *Consumption Supervisor* and the *Consumer Portal Content Editor*, both administrative users of the water utility company. It is organized in three main sub-components: a *Consumption Monitor*, which allows the Consumption Supervisor to check the consumption data of specific consumers; the Customer Consumption simulator, which allows the Consumption Supervisor to run simulation based on specific simulated incentive campaigns and on the services offered by the Agent-Based Modelling component; and the Utility content editor Portal, which permits the Content Editor to provide content for feeding the Consumer Portal. Both can also enter notifications, water related alerts that will be displayed in User portals.

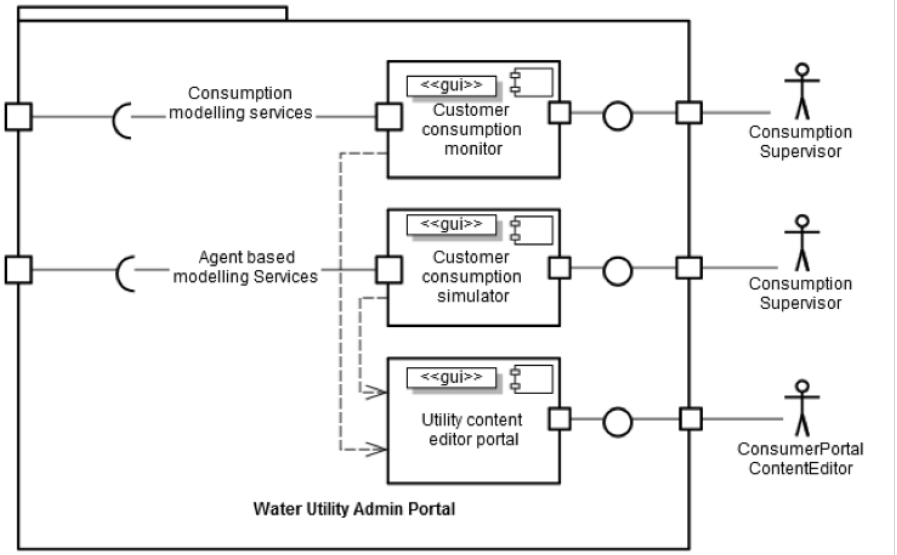

Figure 12: Water Utility Admin Portal Component Diagram

3.7 The Gamification Engine

n the Gamification Engine component is centralized the control of the delivery of incentives in the SmartH2O platform. It "listens" to the actions of the user and transforms them into a variety of rewards, for improving activity and participation. It computes badges, achievements, rewards and all the other gamified features action as incentives for behavior change. In addition, handles the communication between different components of the SmartH2O platform [71].
Its core is the **Gamification Engine Backend**, which is a parametric rule engine transforming actions into points. Data, on the other hand, is stored in a **Gamified Water Meter Database**, in order to decouple the data from the various water utilities portals with the one managed by SmartH2O. It is also provided an ad-hoc UI for the administration of the Gamification Engine to allow the set-up of the parameters of the gamification rules interpreted by the engine itself.
The main concepts of the Gamification Engine are:

- **Gamified Customer Portal**: the GUI visible by costumers that have gamified objects allowed on their profile. It allows them to explore and move towards them.
- **Gamified Engine Admin Portal**: the GUI for admins that allows the utility operator to configure gamifies objects and monitor users.
- **Gamification Objects**: game concepts composing the mechanic of the Gamification Engine (Actions, Badges, Goals, Rewards).
- **Thematic areas**: categories in which gamification objects are grouped and categorized (education, reputation, socialization and consumption).

- **Credits**: points the user can gain performing actions on the portal
- **Action**: a rewarded task a user can perform on the platform (i.e. read a tip, etc.).
- **Badge areas**: category used to group badges to the same topic but different levels
- **Badges**: virtual recognitions assigned to a user and visible to other users in the community. Usually used to demonstrate progress and status. Different actions can be matched to different badges.
- **Goal**: consumption objective that can be achieved by the user reducing the average consumption.
- **Reward**: physical item that can be redeemed by the customer, using credits earned on the gamification platform.

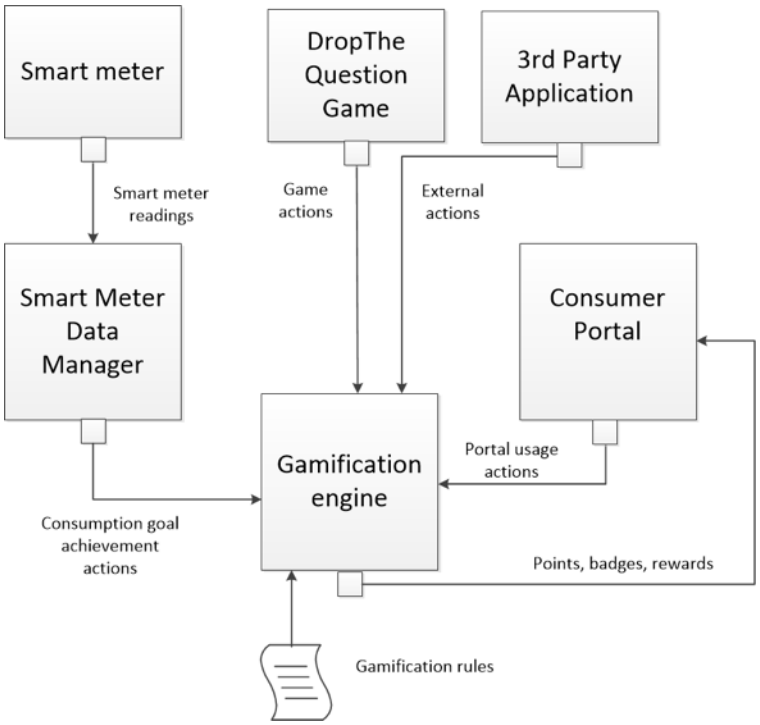

Figure 13: Inputs and Outputs of the Gamification Engine

Actions and badges are grouped in four broad thematic areas:

- **Water Saving**: refer to actual water saving as metered by smart meters.
- **Water Saving Insights**: refers to learning how to save water.
- **Engagement**: refers to activity in the portal and within the community.
- **Profiling**: refers to data input about the household.

Across such areas, there are four major categories of actions, based on the source where they come from:

- **Consumption actions**: these actions derive from the smart meter read-

ings. When the consumption data are received, they are elaborated to check that some of the water saving goals has been achieved (e.g., reduction of X% over the baseline average consumption of a period, such as week, or month).

- **Portal usage actions**: these actions are generated as consequences of the user activity in the Consumer portal (e.g., reading tips, etc.).
- **Gameplay actions**: these actions are produced by the *Drop!TheQuestion* game and correspond to the correct answer to a water education question.
- **External actions**: these actions are produced by external applications, e.g., the pre- existing portal of the water utility.

As has been said before, one of the aims of the Gamification Engine is to assign score to the user according to actions the user itself perform on the portal. The algorithms for action recognition and score assignment differ according to the source of the action and the synchronicity of the rule engine computation. Sources are recognized thanks to parameters the action is made of. Consumption actions are evaluated synchronously for all users, when the next batch of smart meter readings is acquired. Other actions – the ones that do not depend on the asynchronous processing of smart meter data – are treated differently: they are triggered by individual users' events, which are managed by means of asynchronous calls to the Gamification Engine.

3.8 The Drop! Game

The introduction of a platform for handling Games in the SmartH2O project derives from the need of being able to attract the interests of users which are not strictly linked with water utilities – as described in Chapter 2 – while being able to run even as a standalone component [71].
The **Games Platform** is a central component that handles the communication with the main SmartH2O platform ad takes care of managing user's registration, profiles and keep track of the gameplay sessions of the players. The points and the achievements collected in the digital games should be transferred towards the **Gamification Engine**, as has been said before, to create a link between the two approaches for engaging the users. For these reasons, a dedicated database takes care of storing the users and their details, gameplay session data, point and achievements obtained within the games platform.
The game is a quiz game called **Drop!TheQuestion**, that is the digital extension of the **Drop! Board game** and is used to collect behavioral data from the user.
The **Drop! board game** exploits a very popular home and family-oriented entertainment scheme, technically called "*press your luck*", also known as "*push your luck*". Games in this class are games where the players repeat (a part of) an action until they decided to stop due to increased (or not) risk of losing points or the next turn. *Press Your Luck* games include both Risk Management and Risk Valuation games, in which risk is driven by the game mechanisms and valuing how much other players value what you also want, respectively. Examples of this typology of game are:

- *Can't stop* (dice game): claim three of the columns before any of the other players can.
- *Incan Gold* (card game): at each round, a card is revealed. It can be a treasure of a trouble. Players have to choose to continue deeper into the cave or leave.
- *Formula D* (hybrid game): racing game. Players must decide whether to modify their speed at each turn or not: they could win the rice faster or overshoot a turn, losing the game.

Drop! Board Game is designed around the idea that "*a game does not need to be educational, to be… educational*": children learn from games, because playing is the natural way to improve their brain skills [68]. The majority of games are naturally educational, because they have metaphoric meanings that children perfectly understand.

Lily is the main character. She is a young and very clever girl, knowing exactly how to use water in the proper way. She's much more aware about the water wasting problem than her relatives. But she's also got a **monster friend** hidden in the wardrobe. He's not evil, it's just a little goofy and he tries to do exactly the same things done by Lily, but always in the wrong way (Figure 14).

The game is based on a simple – but not meaningless – luck system. The cards showing Lily are always good cards and they let the player score positive points, while the monster cards could be bad and give players negative points. At the end of the game, players can transform the negative point monster cards in positive points, by answering a question on their mobile phones or tablets unlocked thanks to such bad cards. The metaphor is very simple: *you are not winning because of your knowledge, but because you are teaching the monster to behave* [68].

The game equipment comprises:

- A deck of 50 high-quality, colored cards.
- 50 point markers, in colored lucid cardboard.
- The multilingual rule sheet.
- The game box, in high quality colored cardboard, with the game logo and the characters.

The *press-your-luck* genre create excitement, tension, and player choice into what essentially is complete random chance. This game emphasizes the challenge: "how far can you go?", "how long can you last?", etc.

Figure 14: Examples of Drop! Cards: Lily and the monster characters

Any press-your-luck game has two sides to it: on one side, players have the accumulation of points. Usually, the longer one continues risking, the more points he/she might score. The other side of this is the impending approach of failure.

Drop!TheQuestion Digital Game has been developed under the concept of *trivia games*. Trivia games are a popular class of multiplayer games without elimination, in which everyone can play along to the end.

The most popular example is the Trivial Pursuit board game [96], in which winning is determined by a player's ability to answer general knowledge and popular culture questions.

The game is designed to be activated on mobile phones and tables, after a round of the Drop! board game or in a standalone manner. On monster's cards there are QR-Codes that can be scanner out with the mobile or tablet Drop!TheQuestion app to answer questions and to convert bad points in good points.

As can be seen by the app's screenshots (Figure 15), If the user provides the wrong response, the game emits a gentle warning. On the other hand, if the user provides the correct response, the game cheers her/him up.

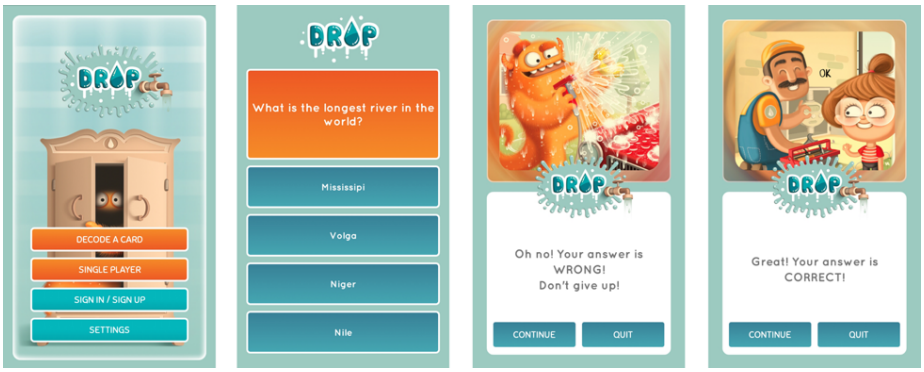

Figure 15: Examples of Drop!TheQuestion mobile game

The implementation of the Drop!TheQuestion digital extension of the Drop! card game has been finalized with the integration into the SES and Aguas de Valencia pilots. This has required the development of the following additional functions:

- **Question editor**: web application for the utility content manager, who can edit the questions and set their properties (answers, correct answer, language, difficulty level, etc.)
- **Crowdsourcing translation application**: web application for voluntary crowdsourcing the translation of questions from a source to a target language.
- **Email sign-up and sign-in**: the extension of the sign-un and sign-in procedure in the game is required to enable the integration of Drop!TheQuestion with the smartH2O platform and enable the association of points to the successful answer to a Drop!TheQuestion question.
- **Identity reconciliation**: the identity of the player user must be communicated and expanded into an identity for the Consumer Portal user if a he/she, registered in the mobile digital game Drop!TheQuestion, later decides to join the community of his utility company.
- **Game Usage Monitoring Tool**: a web dedicated application has been developed for the utility company operator, to enable the monitoring of the users' performance in the Drop!TheQuestion mobile game.

4 Analysis and design of the SmartH2O mobile application

4.1 Requirement analysis

In this section there is a brief summary of the main functional and non-functional requirements for the development the SmartH2O mobile app. Then a deeper explanation will be made according with the main use cases studied.

4.1.1 Functional

This section presents the high-level functional requirements that explain the core functionality of the mobile version of SmartH2O application, some of them are the same of the Customer Portal (web version) . The requirements will be elaborated in the following sub-sections, which describe the separate use cases.

1. The application should allow the user to login into the portal and visualize it in mobile version
2. The application should allow the user to register to the portal (Swiss plot only).
3. The application should show the consumption data visualized by different periods of time.
4. The application should provide some typical consumption metrics, e.g. peak, average of the metered household.
5. The application should provide disaggregated water consumption information.
6. The application should provide some basic water saving tips.
7. The application should provide push notifications.
8. The application should allow the user to see all his previous notification received.
9. The application should allow the user to cancel past notification received.
10. The application should allow the user to stop receiving all or selected notifications.
11. The application should be available in the national language(s) of the users in each case study area, e.g. in Valencian for Valencia case study.
12. The application should enable users to set and visualize their own water consumption goals according to the reading granularity of the user.
13. The application should be able to provide water saving actions.
14. The application should enable users to claim a won reward.
15. The application should display the leaderboard of the gamified water saving competition.
16. The application should let the user easily see the top 3 users and its rank in the leaderboard.
17. The application should keep synchronized action performed on the mobile app with the ones performed on the web portal.

4.1.2 Non-functional

Below, there is a list of high-level non-functional requirements, more deeply elaborated in section 4.1.3 according with the main use cases.

1. The application shall be accessible and useable for non-technical audiences.
2. The application shall be well documented and described.
3. The application shall work properly on different versions of Android OS or screen sizes.
4. The application shall work properly without anonymous behavior (such as crashes, unexpected screens or text or infinite loading).
5. The execution time needed to load data (i.e. the consumption histogram) should be small enough to let the application performing well without annoying the user
6. Every error the application will generate shall be well documented and explained to the user and do not cause the non-usability of the app itself.

4.1.3 Use Cases

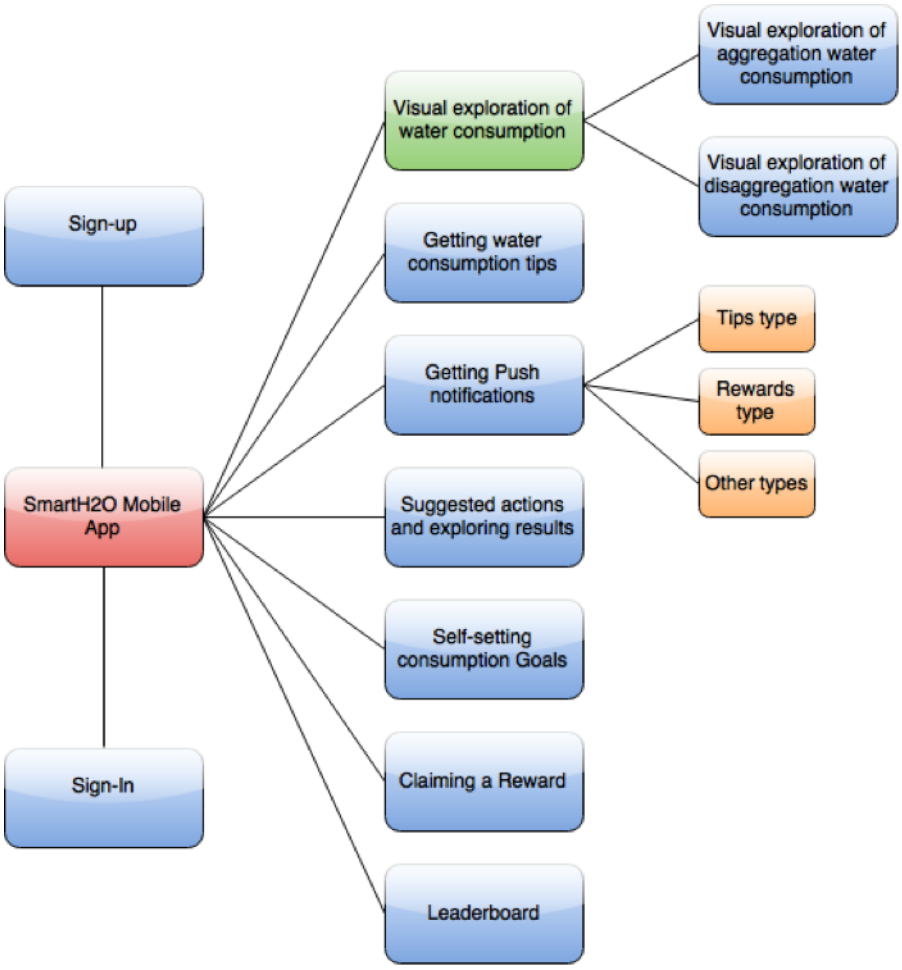

Figure 16: Use cases overview

1. Portal Sign-up (Swiss plot only)

Goal in context	The consumer performs a registration to the Water Utility Customer Portal; his data are saved into the SmartH2O DB.	
Preconditions	The consumer is a client of the utility that manages the portal.	
Success end Condition	The user becomes a Customer user, who can access the Utility Portal and the Mobile app. The consumer is correctly saved into the DB.	
Failed end Condition	• A registration with the specified email already exists, this registration is canceled and the user is notified. • The provided Utility Code does not exist or does not match the user information, this registration is canceled and the user is notified.	
Primary, secondary actors	Customer user, application, ESB, SmartH2ODB, Authentication Gateway	
Trigger	The user click on the Sign-up button in the homepage of the application.	
Description	Step	Action
	1	the Customer requests the registration UI.
	2	the Customer fill and send the registration form
	3	Water Utility Customer Portal verifies if the email was already registered
	4	Water Utility Customer Portal verifies if the Utility Code exists and is valid
	5	Water Utility Customer Portal saves the new user into the SmartH2O DB

Table 2: Sign-up Use Case

Functional requirements

1) The application should allow the user to register to the portal
2) The application should remember user data

2. Portal Sign-in

Goal in context	Raising individual water consumption awareness by visualizing the same UI and information provided by the Web Portal.	
Preconditions	The user is registered in the Web Portal	
Success end Condition	First page of the mobile app is visualized.	
Failed end Condition	First page of the mobile app is not visualized.	
Primary, secondary actors	Customer user, application, ESB	
Trigger	The user inserted the correct username and password in the login page of the application.	
Description	Step	Action
	1	The user inserts his/her username and password in the login page of the mobile app (if the user doesn't remember the password there is a section to reset it and receive the new one by email).
	2	The application communicates with the server part (ESB) to authenticate the user. The authentication phase is performed trough a ticket exchange between the application and the ESB
	3	All the information about the user are stored so that the user shouldn't inset them again at next app startup

Table 4: Sign-in Use Case

Functional requirements

1) The application should allow the user to login into the portal and visualize it in mobile version.
2) The application should allow the user to receive a new password in case he/she forget it.
3) The application should remember user data

3. Visual exploration of Individual water consumption (from history)

Goal in context	Raising individual water consumption awareness by visualizing end use consumption.
Preconditions	The user has his consumption stored in the Smart Meter Data Manager and SmartH2O Database.
Success end Condition	Water consumption is visualized.

Failed end Condition	Water consumption is not visualized.	
Primary, secondary actors	Customer user, application	
Trigger	• User navigate through the menu to the Consumption section. • User click on the "Expand" button in the summary of his/her consumption in the Homepage of the app.	
Description	Step	Action
	1	Accurate daily disaggregated visualization: the application visualizes the smart metered water consumption information of the household. A dashed line represents the average value of the consumption for the selected granularity. By default, the last seven days' consumption is shown.
	2	The user can interact with the visualization, e.g. by choosing different timespans levels of the data swiping left/right over the bar chart.
	3	The user can change the visualization of the consumptions (granularity) by clicking on the drop down menu. The user can see daily, weekly or monthly consumptions. If allowed, by clicking on a bar on the chart relative to a specific day consumption, hourly consumption will be displayed
	4	The user can flip the smartphone in order to see a different visualization of the consumes: 1) The user is allowed to see the hourly visualization of the consumed: hourly consumption is displayed 2) The user is not allowed to see the hourly visualization of the consumes: a larger timespan of daily consumption is displayed.

Table 6: Visual exploration of Individual water consumption (from history) Use Case

Functional requirements

1) The application should provide the option to adjust the view settings of the visualization to different time intervals and time granularity.
2) The application should provide some typical consumption metrics, e.g. peak and average of end use events.
3) The application should provide users the option to compare their current consumption with their own average consumption (self-comparison).

4. Visual exploration of individual water consumption (current)

<table>
<tr><td>Goal in context</td><td colspan="2">Raising individual water consumption awareness by visualizing current day/week/month consumption data.</td></tr>
<tr><td>Preconditions</td><td colspan="2">The user has his consumption stored in the Smart Meter Data Manager and SmartH2O Database.</td></tr>
<tr><td>Success end Condition</td><td colspan="2">Water consumption is visualized.</td></tr>
<tr><td>Failed end Condition</td><td colspan="2">Water consumption is not visualized.</td></tr>
<tr><td>Primary, secondary actors</td><td colspan="2">Customer user, application</td></tr>
<tr><td>Trigger</td><td colspan="2">• User logs into the application (first login or opening the app after registration).
• User navigate through the menu to the Improve Yourself section.</td></tr>
<tr><td rowspan="3">Description</td><td>Step</td><td>Action</td></tr>
<tr><td>1</td><td>Accurate visualization: the application visualizes the aggregate, smart metered water consumption information of the household. By default, the daily consumption is shown displayed calculated over the current week – if allowed, otherwise the weekly or monthly visualization is shown.</td></tr>
<tr><td>2</td><td>The user can compare its consumption with his average consumption calculated on the current week (daily), the previous week (weekly) or the previous month (monthly).</td></tr>
</table>

	3	The user can change the visualization of the consumptions (granularity) by clicking on the drop down menu. The user can see daily, weekly or monthly aggregated consumptions data. For weekly and monthly visualization, if allowed, a yellow goal box visualize the available goals that the user can set up or the consumption quantity threshold below which the user should stay in order to fulfill the goal. In the base value blue box, a user can see the average value of consumption for the selected granularity calculate from the beginning of the metering.

Table 8: Visual exploration of individual water consumption (current) Use Case

Functional requirements

1) The application should provide the option to adjust the view settings of the visualization to different time granularity.
2) The application should provide some typical consumption metrics, e.g. average of end use events.
3) The application should provide users the option to compare their current consumption with their own average consumption (self-comparison) according with the granularity.
4) The application should provide users the option to compare their consumption with consumption goals set by them, by the application and / or by the utility (goal comparison).

5. Getting water consumption tips

Goal in context	Raising individual water consumption awareness.	
Preconditions	List of water saving tips is defined.	
Success end Condition	Tips are displayed.	
Failed end Condition	Tips are not displayed.	
Primary, secondary actors	Customer user, application	
Trigger	User navigate through the menu to the Tips section.	
Description	Step	Action
	1	System provides user with different water saving tips.
	2	User can navigate through them and mark them as read, gaining the associated points.

Table 10: Getting water consumption tips Use Case

Functional requirements

1) A non-disruptive warning shall alert the user if no internet connection is available and no tips are stored
2) The application should provide a 'tip of the day' notification for a random water management tip displayed every day.
3) The application should allow the user to browse through past tips.
4) The application should save tips to permit offline visualization.

6. Getting push notifications

Goal in context	Informing user about news, portal activity updates, e.g. new achievements, tips, rewards and problems.	
Preconditions	• The user must have notification enabled both in his OS and inside the application. • The user's smartphone must support the registration to Google Play Services (further information in next sections)	
Success end Condition	A notification is visualized in the user's notification center.	
Failed end Condition	Notification is not visualized.	
Primary, secondary actors	Customer user, application	
Trigger	• The user receives a notification. • User navigate through the menu to the Notification section.	
Description	Step	Action
	1	The user receives the notification. He/she is able to see the title of the notification, an excerpt of the body, the primary icon (depending on the topic of the notification) and the secondary icon (identifying SmartH2O app). He can click on it or discard it.
	2	Once clicked on the notification the user is redirect to a page displaying the icon, the title and the full text of the notification.

	2A	If the type of the notification is "reward", in the full-notification page, the user can see a button that will redirect him to the rewards section, displaying the reward mentioned in the notification.
	2B	If the type of the notification is "tips", in the full-notification page, the user can see a button that will redirect him to the tips section, displaying the tip mentioned in the notification.
	3	Whether the user discard the notification or displays it, past notification are saved in the application's database so the user can see them in the Notification tab in the menu. The user, then, can cancel them forever.

Table 12: Getting push notifications Use Case

Functional requirements

1) The application should be able to receive notification.
2) The application should be able to manage different type of notification triggering different types of events.
3) The application should be able to show and save notifications and display them to the user.
4) The application should allow the user to browse through past notifications.
5) The application should mark past notifications as read and highlight new ones.
6) The application should allow the user to turn off/on notifications.

7. Suggested actions and exploring results

Goal in context	Stimulating water consumption awareness through gamification.	
Preconditions	The user profile is linked to the Gamified Engine.	
Success end Condition	The user's status (points, badges, etc.) is correctly updated and visualized.	
Failed end Condition	The user's status (points, badges, etc.) is not correctly updated.	
Primary, secondary actors	Customer user, application	
Trigger	User completes suggested actions in the homepage of the application.	
Description	Step	Action

	1	The user can collect credits and reputation points through his actions on the portal. Actions can be automatically detected or explicitly declared by the user.
	2	After doing an action, the status of the user in the homepage summary must be updated.
	3	User can redeem collected credits for different kinds of rewards (offered e.g. by the utility).

Table 14: Suggested actions and exploring results Use Case

Functional requirements

1) The application should display user progress, in terms of badges and credits collected.
2) The application should display available rewards and credits required to redeem them.
3) The application should notify the user in case of achievements.

8. Self-setting consumption goals

Goal in context	Stimulating water saving by setting consumption goals.	
Preconditions	Customer household is smart metered and the user profile is linked to the Gamified Engine.	
Success end Condition	Consumption goal was set.	
Failed end Condition	Consumption goal was not set.	
Primary, secondary actors	Smart-Metered Customer user, application	
Trigger	User sets consumption goal.	
Description	Step	Action
	1	The user can set a consumption goal for himself, to stimulate better consumption. Goals are divided for granularity (daily, weekly, monthly) and are enable for the user to be set according to his/her granularity. Each goal has a value (5,10,15) and a score assigned. Fulfilling a goal means earning such associated points.

	2	By selecting one goal in the goal box and clicking on the button at the bottom of such box, a user can set up a goal. • If the user is not allowed to set up a goal for the selected granularity, the checkbox and the button are not displayed and the Goals box is filled with informative text. • If the user has already set up a goal, such a goal is displayed for the selected granularity in the goal box • If the user can select a goal, a checkbox with goals values and point and a button are enabled in the Goals box for such granularity.

Table 16: Consumption goal setting Use Case

Functional requirements

1) The application should enable the customer to set his own goal within the specified granularity.
2) The user should only set one goal at a time per granularity.
3) The application should visualize the progress of the household's average consumption with respect to the consumption goal.

9. Claiming a reward

Goal in context	Stimulating water consumption awareness through physical rewards.	
Preconditions	The user profile is linked to the Gamified Engine .	
Success end Condition	Reward is redeemed.	
Failed end Condition	Reward is not redeemed.	
Primary, secondary actors	Customer user, application	
Trigger	User redeem a reward.	
Description	Step	Action

	1	The user can navigate through the available rewards in the Rewards page. For each reward, the user can see the status of the reward (available, claimed, etc.) and, in case of a point-rewards, the amount of points the user need to claim that price.
	2	Clicking on a Reward, the user can see the full description and rules of that specific reward. If it's available, the user can claim it, receiving a claim id useful to track and receive the gift.

Table 18: Reward claiming Use Case

Functional requirements

1) The application should allow the user to navigate through the rewards
2) The application should be able to update the status of the rewards
3) The application should save rewards in the internal database for offline visualization
4) The user should be notified if he/she wins a reward
5) A non-disruptive warning shall alert the user if no internet connection is available and no rewards are stored

10. Accessing the Leaderboard

Goal in context	Stimulating water saving by providing gamification mechanisms to the utility customer.	
Preconditions	The user profile is linked to the Gamified Engine and he enters in the gamified competition (leaderboard opt-in).	
Success end Condition	Leaderboard is visualized.	
Failed end Condition	Leaderboard is not visualized.	
Primary, secondary actors	Customer user, application	
Trigger	• User logs into the application (first login or opening the app after registration) • User navigate through the menu to the Leaderboard section	
Description	Step	Action
	1	The user can see his/her rank in the 7-days or All leaderboard and the ranking and points of the other customers.

Table 20: Leaderboard visualization Use Case

Functional requirements

1) All the information about each user should be displayed
2) The current user name should be highlighted
3) A non-disruptive warning shall alert the user if no internet connection is available

11. Usage Logger

Goal in context	Studying the behavior of the users in order to improve the motivational mechanisms.	
Preconditions	The user is logged in the mobile app.	
Success end Condition	Usage Logger is successfully stored.	
Failed end Condition	Usage Logger is not successfully stored	
Primary, secondary actors	Customer user, application	
Trigger	• The user kills the app • The system kills the app	
Description	Step	Action
	1	Every action the user performs using the mobile application is registered in a special object called Loggable Event. Once the app is killed, the usage logger (the sum of all the Loggable Events) are sent to the Gamification Engine..

Table 22: Usage Logger Use Case

Functional requirements

1) The most meaningful actions performed by the user using the application should be registered

4.2 Design

4.2.1 Data structures

According to requirements illustrated in in the previous subsection, in this section there will be a brief description of the data structure implemented in SmartH2O mobile app.
All data objects usage and implementation are based on the Gamification Engine data model which created the main concepts around which all the application is developed.

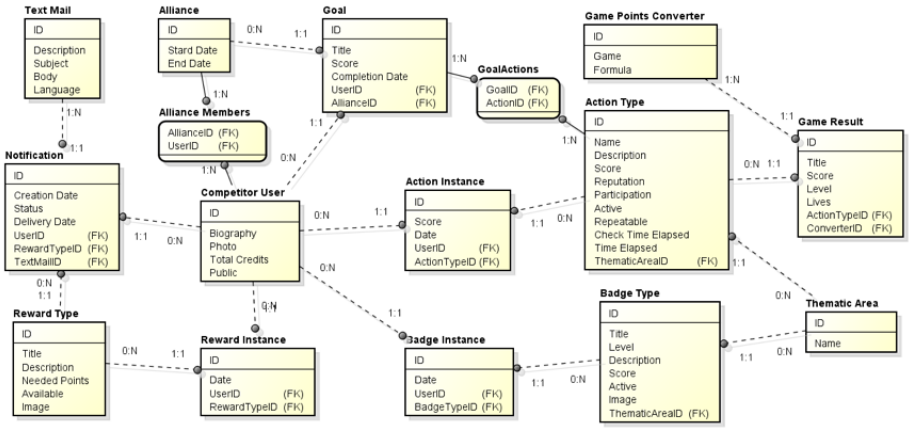

Figure 17: Gamification Engine relational mode

The concept of **Action** is the basis of this application. The user can perform action all over the application: reading a tip, claiming a reward, etc. Thus, each action is associated with a type (**Action Type**). Each Action Type is identified by its name, description and score. The Thematic Area ID represents the content area in which such an action is performed, such as water consumption. Each action has associated a score, that is points given to the user for performing such an action. Actions are mapped with the concepts of: goal, tip, reward, and notification. Action Type is a concept used to connect each Action to the actual **Action Instance**, that is the action performed within a specified context (e.g., reading a tip by a specific user).
In the application there is also the concept of **Suggested Action**, that is an action (e.g., visiting a website) proposed to the user to increase his/her awareness about the concept of water consumption.
To improve self-confidence of a user, to show off his/her status in the community in which he/she belongs – as has been said, for social comparison theory, social motivations are triggered by providing social recognition and status in the player community – and to keep track of his personal increasing knowledge about water consumption, badges have been introduced. A **Badge** is identified by its type (context in which it has been won), the date of winning and a label representing the name. A **Badge Instance** is a badge won by the user, performing actions and earning points.
In order to incentivize the user to perform actions on the portal – such as reading tips, setting up goals, etc. – to increase his/her knowledge about water consumptions, physical rewards have been introduced to let the user convert its earned point into gifts. The following entities has been implemented:

- **Reward Type**: identified with its id, has a description part composed by the name (title), description, rules (how to win it), score needed to claim it, Figure, and a Boolean *available* value that represent the availability of that reward.
- **Reward Instance**: is the actual reward that is available to the user

registered in the system. In the application, the status of the reward is managed allowing the user to know how many points he/she needs to claim it and the tracking status if the reward has been redeemed.

To gain more points and badges (and then to save water) the user is incentivized to set up a personal goal to spend less water in his/her home or garden, staying below the set up water consumption threshold. The **Goal** entity, in the application, is characterized by its id, the granularity (daily, weekly, monthly), the percentage value (5,10,15), the Boolean values *active* and *self* (meaning that the goals is settable or has been already set up) and the corresponding *action type*. **Goal Action** is the effective action done by the user setting up that specific goal, earning the corresponding points if fulfilled.

To encourage a rational use of water and increment users' awareness, some tips are provided to the consumers. The **Tip** entity has been introduced: each tip is identified by a remote id (the one returned by the server), the local id (unique w.r.t. the application context), a name and the text content divided into a header and a body. The date is the actual date of creation of the tip, whereas the *read* Boolean value define whereas such a tip has been read by the user or not.

The user must be aware of his/her consumption to gain self-confidence and increase his/her knowledge about how much he/she is consuming. Then two entities have been implemented:

- **Consumption**: identified by the quantity of water consumed by the user and the timestamp of read
- **ConsumptionSummary**: the summary of the water consumed by the user, identified by the averages according to granularity (daily, weekly, monthly), the total amount of water for weekly and monthly measurements of the current month and the *from* and *to* date to define the timespan of the measurement,

As has been said, SmartH2O mobile application is meant to help users to keep track of their consumption wherever and whenever they want. In order to improve the willing to open and use the app, a notification management system has been implemented. Notifications can notify user about the weekly winner of tickets of the Oceanographic museum, new badges achieved, a reward now available, etc. Past notifications must remain reachable and visible to the user in a dedicated section, as the user is habituated to see them (Facebook like mechanism). The **PastNotification** object has then been developed (client side). It's characterized by the information the notification must provide (that is title, message), the type of the notification and the related icon, the intent it's going to send when opened and a *read* Boolean value identifying whether the notification has been read or not.

All the application services mentioned above (reading tips, claiming rewards, visualize water consumption, etc.) are based on the concept of **User**: global and user id are unique ids used to represent the user himself while using different services (gamified or not); email, username and avatar are the personal information of the user and the score is the actual amount of point the user has gained performing actions on the application and saving water.

In order to include the gamified part of the portal in the mobile app, the **User** is extended with his/her **Player** version, containing further information such as ranking and the gamified id (*oid*).
Each action taken by the user toward the application is logged in a file to grab further information about the behavior of users and study it in order to improve the application itself in the future. All the action done are mapped with a **LoggableEvent** object, sent to the server every time the application is closed.

4.2.2 Interface design

Each section has its own accent color according to the Science of Color [97], as they are already present in the Web Portal. Main page, secondary pages and water consumption pages, such as Consumptions and Improve Yourself pages, have a light blue accent color, because it's relaxing and easily linkable to water. Leaderboard has a bright fuchsia color, incentivizing social and community activities. Rewards section have a yellow accent color, inspiring a won price and giving excitement and happiness. Tips section is in green, known as an educational color.
In next pages there will be a brief description of each section with example screenshots taken from the app.

Public Screen

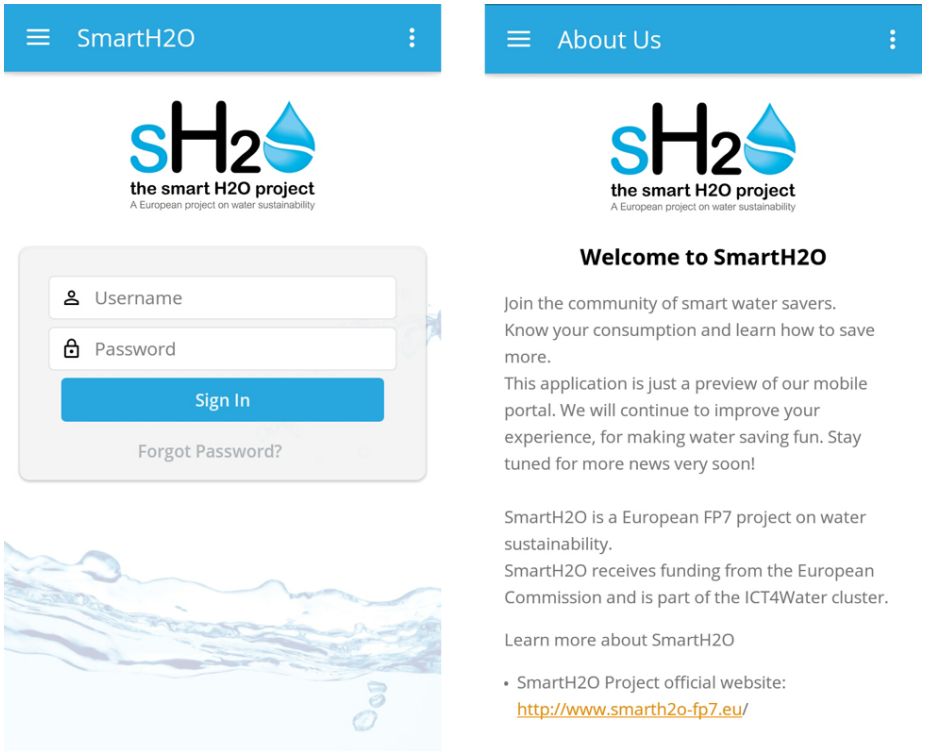

Figure 18: Public screens

The public screen of the mobile app (the ones accessible from non-logged users) provides a login mask (left) and basic info about the project (right) which also links to the official project website. If a user need to reset the password, clicking on the *Forgot Password?* button a mask with an email input for is displayed. The user can fill it with his/her email address to receive an email with the new password.
In order to register to the portal, a user should first navigate to the web portal. After signing up, all users receive an email that points them to the mobile app, providing them with temporary mobile credentials, and, in case they haven't downloaded it yet, it also provides a download link to Google Play.

Home screen and Navigation

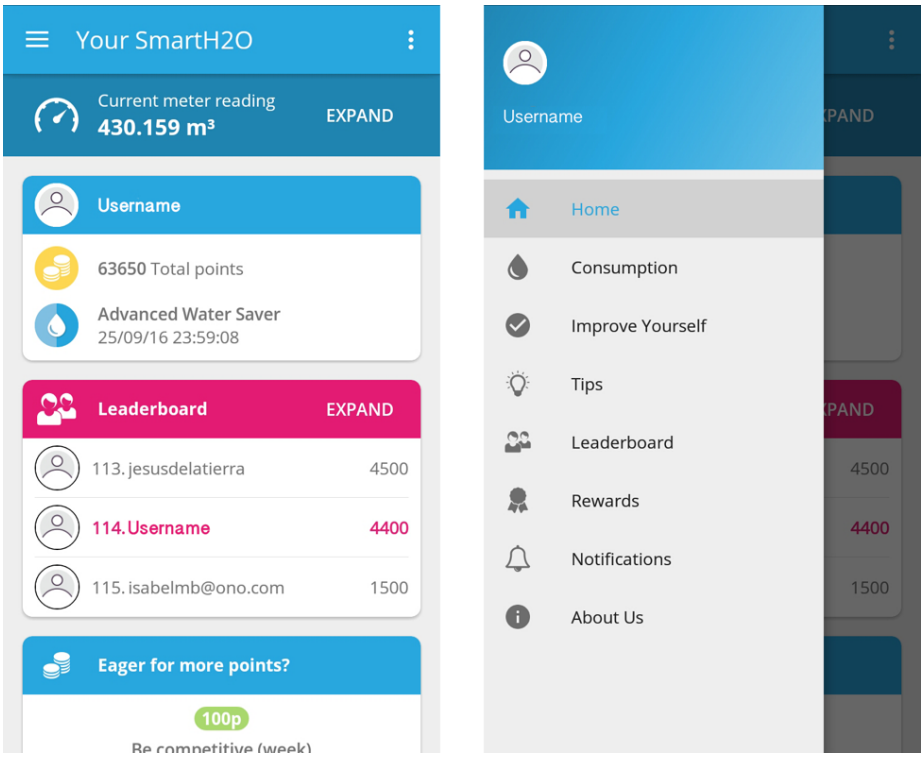

Figure 19: Home screen and navigation menu

In the home screen (left) there is a summary of the user's status with his/her current metering and his/her gamified profile: total amount of points earned, the badges achieved, the ranking on the leaderboard and a selection of suggestion the user can do/read to gain more points.
The in-app navigation menu (right) is accessible swiping left-to-right the screen starting from the left-most margin of the screen or clicking on the three bars next to the application title, following the standard Android design pattern. In this menu users can navigate to the main app elements: their consumption section, the overview visualization with the goal setting mechanisms (Improve Yourself section), a section where they could read water consumption tips, the full leaderboard section, the list of all the notification received and the rewards page.

Detailed consumption bar chart

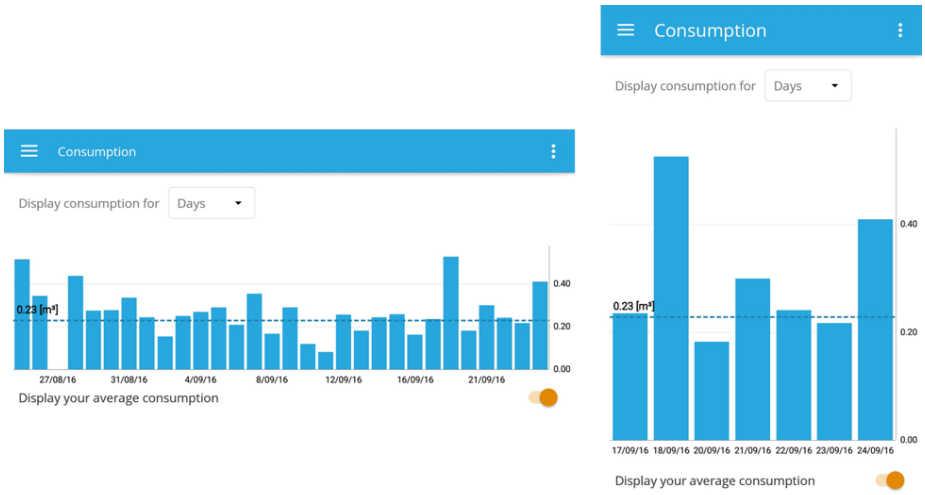

Figure 20: Detailed consumption bar charts

Users can view, explore and filter the bar chart of their consumptions. The dotted line is their average consumption over time. If a user is allowed to, by clicking on a bar he/she could see also the hourly consumption data. Flipping the screen (right) will trigger the hourly consumption for the current day or, if not available, it will display a longer timespan consumption bar chart. By sliding left/right on the char, older/newer data will be displayed. The visualization of the consumptions can be daily, weekly or monthly.

Consumption overview and goals setting

Figure 21: Improve Yourself screen and Goals chart

The pipe visualization of the portal was changed to be more comprehensible on mobile screens. It keeps track of the improvement (or worsen) of the consumption for days, weeks and month (according to the user's granularity, that is, if its consumption readings are daily, weekly or monthly). The upper box represents the consumption. If it's green, the consumption is under the base value of the user. If it's orange, that means that the user is consuming more than usual (more than the goal he set up or more than the 5% less of the base value but still under his base value). If it's red, that means that the user is consuming too much, more than his base value. Clicking on the box, an info text is displayed that could help the user to better understand the numbers he/she is reading.
The blue box represents the base value according to the selected granularity. The base value is the average consumption calculated from the beginning of the readings for such granularity. It's the threshold from which the improvements (or not) in water consumptions are calculated. Clicking on the box, an info text is displayed providing further information about such a threshold.
The yellow box represents the goals a user can/has set. If none are present, according to the selected granularity, the box shows checkboxes that allow the user to set a goal – if he is allowed to – and earn the corresponding points.

Points change according to the cardinality of the goals (weekly if allowed or monthly) and to the value of the goal set-up. If a goal is set-up, the yellow box is filled with information regarding the consumption threshold the user should stay below to in order to fulfill the goal and the points he/she will earn.

Water saving tips and notification settings

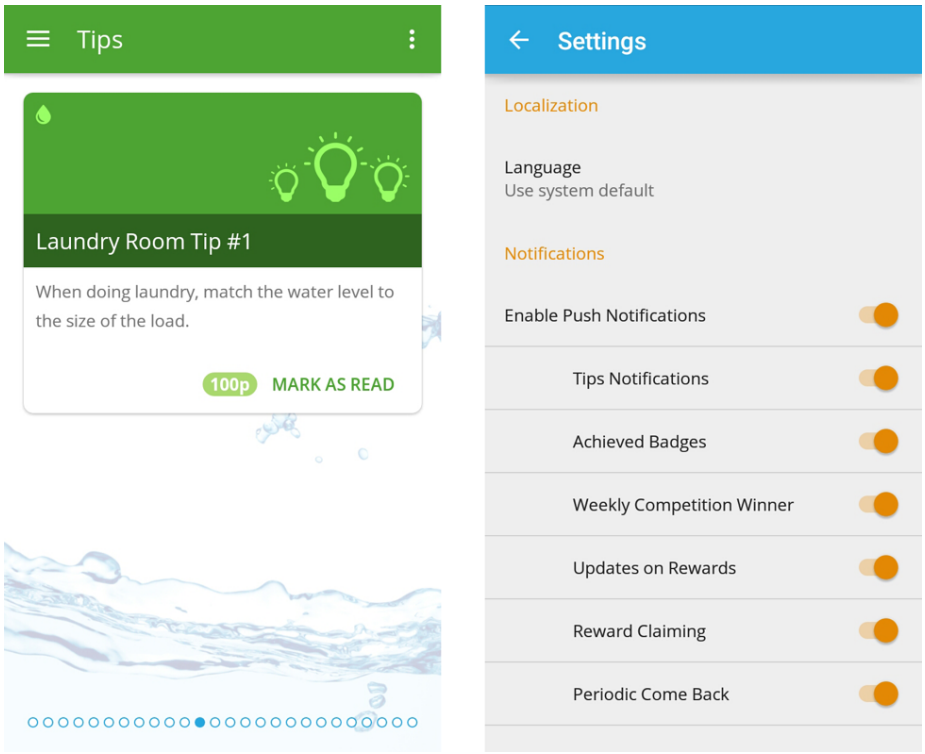

Figure 22: Tips and Settings screens

Tips are presented in a separate page that can be navigated by a simple swipe left / right (left). Like in the web app, users can mark tips as "read" and receive points in exchange for each read tip.
In the settings of the app (right), users can turn and off notifications e.g. for consumption alerts, or to receive tips and news updates on SmartH2O achievements on a regular basis. In addition, a user can decide to change the language of the application, choosing between English, Spanish and Valencian.

Gamification elements: leaderboard and rewards overview

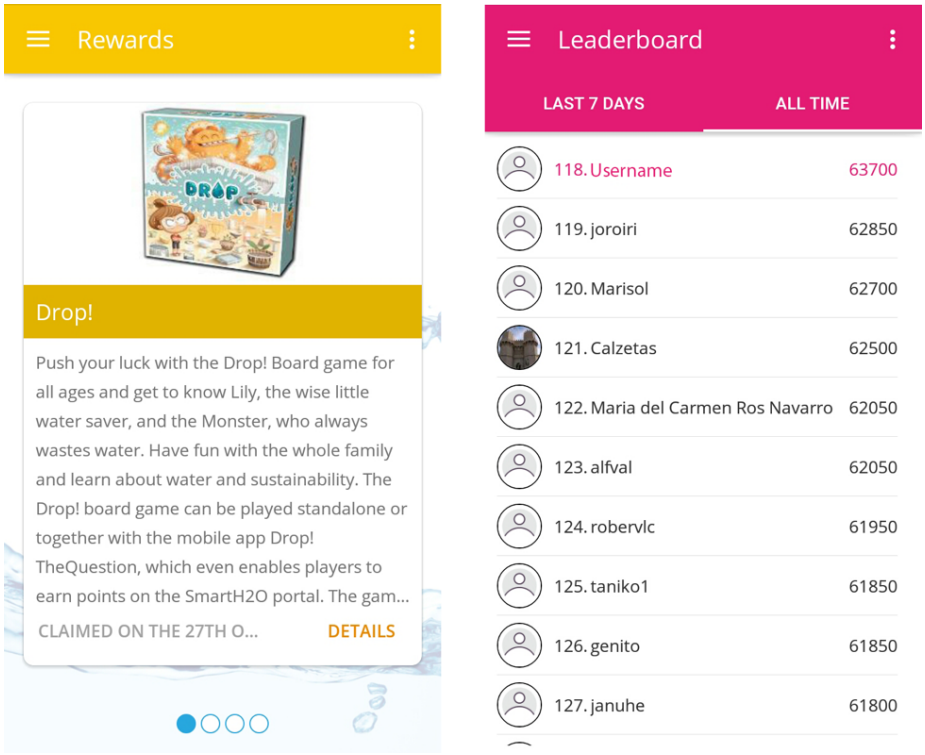

Figure 23: Rewards and Leaderboard screens

Rewards can be viewed and selected in a slider on a separate page (right), using a swipe left / right gesture to view different rewards and tap on details to find out more about each reward.
The leaderboard page can be navigated by a tap on the respective leaderboard type: Last 7 days or All time and the he user's own position is highlighted. If available, the avatar of each user is displayed in lazy loading (left).

Push Notifications

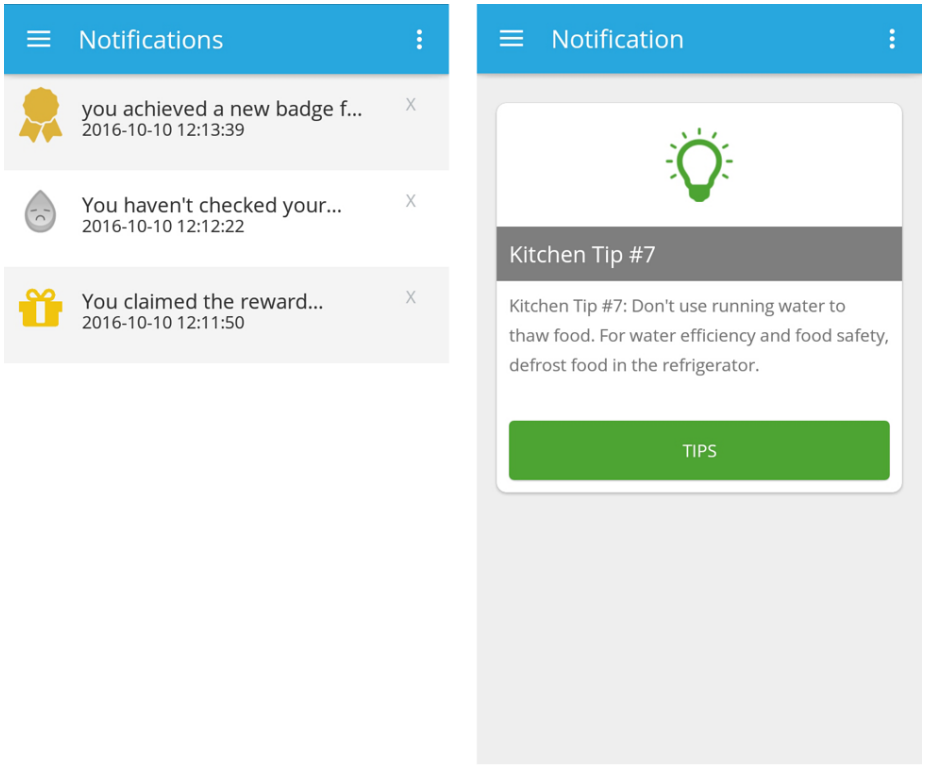

Figure 24: Notification (list and single) screens

Whether the user decide to click on an incoming notification or ignore/discard it, all the notification history is stored in the app's database and displayed as a list in the Notification section (left). Grey rows represent a non-read notification, white rows are read notifications. If a user clicks on a notification (both in the notification panel of the Android OS or the Notification section in the application) a specific behavior, associated to the type of the notification itself, is performed. If the notification is meant to be informative, the full text of the message sent is shown in a specific page, letting the user see the full body of the notification (right). If the notification regards a specific tip or a reward, a button is displayed that allows the user to be redirect to such a tip or reward detail in the corresponding section.

4.2.3 Business logic

The most challenging factors in developing SmartH2O mobile application were: mechanisms to manage the synchronization of data and the design of push notifications. In this subsection there will be an overview of the motivations and the methods adopted for the implementation of those two fundamental

aspects.

4.2.3.1 Data Synchronization mechanisms

SmartH2O application data is based on the Water Utilities, Gamification and Customer Portal databases. Synchronizing such data all together at app startup, could cause decreasing in performances, wasting on user's connectivity data (e.g., 3G data) and possibly causing a slow-down of the application startup. In order to avoid those problems, a specific synchronization mechanism has been introduced according to the type of data to be downloaded and whether to allow the possibility to display such data in offline mode or not. Different methodologies have been applied according to the meaningfulness of such data with respect to the time elapsed since the last synchronization.

- **Tips**: the first time a user logs-in in the application and navigate towards the Tips section, all the tips instances associated to that user are downloaded. According to the management of the Customer Portal, when an Admin adds a tips and it becomes available to the user, a new notification is sent. It has been thought that such an addition won't be performed more than once a day. For that reason, the synchronization mechanism adopted for tips is:
  - *Daily sync*: local variables stored in the local memory of the application take care of checking the timestamp of the last synchronization of the tips. If more than 24 hours have passed, then at the next opening of Tips section, all the tips will be updated.
  - *Notification sync*: if a "new tip" notification is received; the application is forced to update all the tips at next Tips section opening.

  The system can decide to force the update of all data in the application by sending a "server restart" notification.
- *Manual sync*: If a user marks a tip as read, the new status of such a tip is send to the Customer Portal database. To reflect the successfulness of such an action, all the tips are downloaded and stored again.
  See Figure 26 for an explanation of all the steps required for the correct synchronization of the tips. The same sequence diagram can be applied also to the other object synchronization described in the next points.

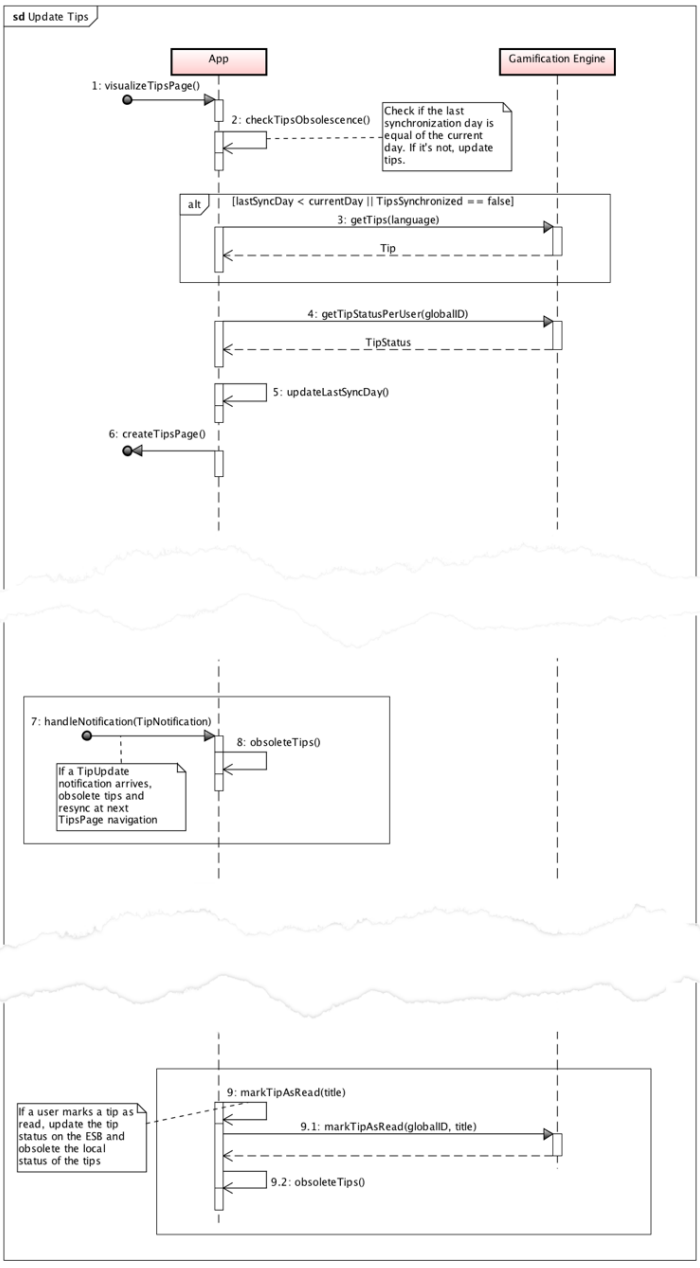

Figure 25: Example of synchronization of Tips in the three cases

- **Rewards**: the first time a user logs-in in the application and navigate towards the Reward section, all the rewards types allowed to the user to

be won are downloaded. Since each user has a different rewards instances, they're downloaded them too, so that each reward type can be updated with the correct reward instance for such a user. Reward types are not frequently updated, whether a user could win a reward in every moment. For that reason, the synchronization mechanism for rewards is the following:

  - *Daily sync for Reward Types*: as tips, local variables stored in the local memory of the application take care of checking the timestamp of the last synchronization of the reward types. If more than 24 hours have passed, then at the next opening of Reward section, all the reward types will be updated.
  - *Continuous sync of Reward instances*: since a user can won a reward (or the status of the reward instance can be updated in every moment, e.g., the shipped status), each time the user navigated towards the reward sections, reward instances are updated.
  - *Notification sync*: if a "new reward" notification is received; the application is forced to update all the reward types at next Reward section opening.

  The system can decide to force the update of all data in the application by sending a "server restart" notification.
- **Leaderboard**: since the leaderboard is a dynamic and continuously updating concept, the synchronization of data is done each time the user wants to see its ranking in the Leaderboard section. It's not available offline and, in case of error or absent internet connection, the user won't be able to see the chart.
- **History/Current Consumptions and Goals**: like Tips and Reward Types, user's aggregate and disaggregate consumption data are updated each day. The first time the user navigates through whether the Consumption or Improve Yourself sections, the data is downloaded and stored in the local database. On the other hand, Goals status is downloaded each time the user wants to see his/her situation in the Improve Yourself section. That's because the reading from the smart meters is done daily and so, once data is downloaded, there isn't the possibility that it could be updated before the next day. On the other hand, a user could set a self-goal in any moment, and so such data must be kept updated.

4.2.3.2 Notification design

Notifications' usage is twofold: on one hand, they let the user being warned or incentivize to use the application, e.g., sending him alerts about new tips or notifying him that he has won a reward. On the other hand, notifications are used to force the refreshing of data at next app's startup. In the latter case, the notification is managed silently in background by the application, updating its internal synchronization mechanism without evidently notify the user about what it's happening.
The first kind of notifications, like the "*weekly winner*" one or the "*come back*", etc., must become visible to the user. It is important that the user can quickly

recognize who is sending such a notification and which is the topic the notification is talking about. Since the application has different type of notifications leading to different type of information and, then, different outcomes for the user, it was important to differentiate them as much as possible, providing a way to let the user recognize them at a glimpse still maintaining clear that the sender is the SmartH2O app. In the end, it was also important to incentivize the user to click on the notification, instead of ignoring or cancelling it, to open the app and to pass him some kind of information. A full detailed explanation of how push notification are managed app side is provided in subchapter 5.4 (Figure 18 explains how the communication with the push notification server works).
To develop a notification management service that could satisfy such goals, the Android Notification Design Pattern has been followed.

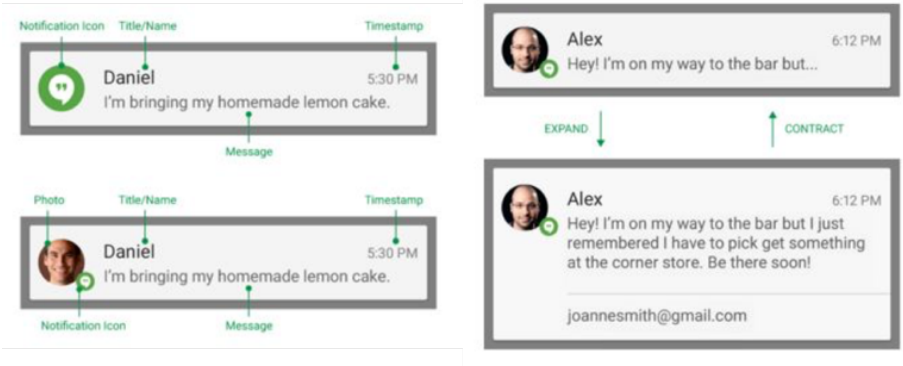

Figure 26: Example of Notification following the Android Design Pattern

Figure 26 displays all the information that Android OS allows to show/hide in the notification, such as:

- *Icon*: a notification can display the only app's icon or a combo of photo and app's icon on the corner
- *Text*: a notification can display the full text of the message or just a part. In this case, the notification could be set up in a way that, with a swipe of the user, it will expand and visualize the full body or not.
- *Grouping*: the managing of incoming notification can be done in two ways. The first way allows a newer notification can overwrite a past one (displaying only the latter in the notification tab of Android OS). The second way allows different notification to be displayed in a separate notification object remaining all listed in the notification tab on the OS.

According to those possibilities, the following are the design decisions and the motivations that have led to the current implementation choices:

- **Disabling expansion**: disabling the expansion of the notification, the user wont' be able to see the full text of the notification in the notification tab of his smartphone. If he wants to read it, he must open it. This decision will encourage the user to click on the notification he receives

and to open the application. This will lead to an increase of the user awareness about water consumption due to the navigation through the application and the reading of the information provided.

- **Using two icons**: using two icons for the notification (in Figure 26 called *Photo* and *Notification Icon*) is useful to distinguish the topic of the notification still having clear which application is sending it. The *Photo* part will contain the icon relative to the type of the notification: a gift for a reward notification, a green lamp for tips, etc., while the *Notification Icon* will be the icon of SmartH2O application, that is the water drop.
- **Overwriting notifications**: according to the type of the notification, if more the one arrives to the user while he hasn't already read an older one, the notification can be overwritten or not. Notifications like "*tip of the day*" are never overwritten: the user is redirected to different information with respect to the different tip of the day. This means that the user should be able to access all the different information he receives, even an older one. For notifications like "*come back*", they are overwritten: this kind of notification will incentivize the user to open the application again. It doesn't give further information to the user, so if two or more notifications of this type arrive, only the latest one is displayed.
- **Enabling/Disabling notifications**: the user will be able to disable/enable notification in the Settings tab. He can decide whether to disable all notifications or just a selected number of them. This will encourage the user to not disable all the notification, given the opportunity to disable only the ones he wants to. This will permit the system to keep sending a subpart of notifications to the user.
- **Logging**: the reading or the discarding of a notification is an action mapped in a *Loggable Event* object. When the notification is clicked by the user, it is marked as *read*. If the user discards the notification (from the notification center of his smartphone) the notification is marked as *canceled* but it remains *unread*. The read and unread notifications (even if they are discarded or not) will be present in the Notification section inside the application.

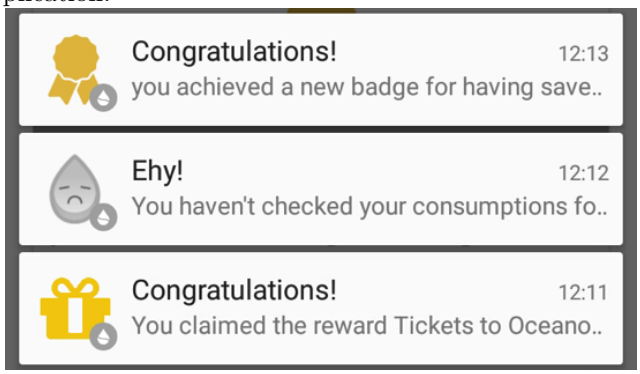

Figure 27: Example of incoming notifications

5 Implementation of the SmartH2O mobile application

The mobile version of SmartH2O social awareness application is developed in native Android, Java based language. The minimum version of the SDK is the 15 (OS>= 4.x Ice Cream Sandwich) and the target SDK used is the 23. The latest version of the android SDK is the 24, but the application is built in API 23 level for compatibility with other components.

5.1 Why Android

The choice of building an application in Android native language is based on manifold motivations:

- **Easiness**: Java language is well known by almost every computer science engineer or student, leading to a continuous development and updating in time passing the baton to different developers. In addition, to develop an application for iOS devices, a developer must use a Mac, while Android app development can be done on Windows, Mac and Linux OS.
- **Market Share**: Android phones are present in a larger number with respect to Apple or Windows Phone smartphones due to the wide range of prices and model that are sold. It's easier to find at least one android phone per family. For an application dealing with the water saving problem, it's very important to reach from the beginning the widest percentage of people. The estimated total number of Android devices in the hands of consumers, as at December 2014, lies north of 1.6 billion [79]. Then, Android absolutely dominated the number of smartphones shipped worldwide in the second three months of 2016, with 87,6% market share [87].
- **Alpha/Beta release**: being a prototype, the mobile version of SmartH2O application should have firstly released in alpha version, then in beta and then in the final public release. The *Google Play Store*, the place where all Android user can download applications on their phones, is the easiest place to publish an alpha/beta version for the application. It has the ability to release an app with restriction and authorization mechanisms, being available only to members of a selected group of testers. With this, a developer can provide early access to a subset of users, and use their feedback to polish the app before finally releasing it to the general public. In addition, a gradual/staged roll out of an update can be performed. With the staged rollout, only a specific percentage of users could get the update, and the feedback and crash reports can be monitored before increasing the percentage of users to receive the update [77].
- **Availability**: apps deployed to the Google Play store are available for download by users within a few hours, compared to a few weeks for Apple's App Store.
- **Price**: as has been said before, to develop an application for iOS devices, a developer must use a Mac, while for Android app development he can

use Windows, Mac and Linux platforms. Also, registering as a developer on the Apple App Store requires a yearly fee of $99, whereas registering as a developer on the Google Play Store requires a one-time only payment of $25 [77].

5.2 Libraries used

For the development of the mobile version of SmartH2O social awareness application, several libraries have been used. In this section there will be an overview of what has been imported with a brief description of each library:

- **Android support library**: it offers a number of features that are not built into the Android framework. These libraries offer backward-compatible versions of new features, provide useful UI elements to implement the recommended Android layout patterns that are not included in the framework, and provide a range of utilities that apps can draw on [90].
  - **Backward Compatibility**: it allows apps running on older versions of the Android platform to support features made available on newer versions of the platform. If the app incorporates the *Support Library's appcompat library*, and this is the case, the app has access to many of the features available in API level 21, including support for material design (such as the *ActionBar*, the *Drawer Menu*, etc. even if they're not present in lower API levels). As a result, the app can deliver a more consistent experience across a broader range of platform versions.
  - **Support for General Layout Patterns:** Support libraries provide user interface elements not offered by the Android framework. For example, the Android Support Library offers additional layout classes, like *DrawerLayout*. These classes follow recommended Android design practices; for example, the Design Library follows the principles of *material design* – that is, a comprehensive guide for visual, motion, and interaction design across platforms and devices – in a way that works across many versions of Android [90]. In the application development such design elements have been used several times. For example, the *DrawerLayout* has been used for the implementation of the navigation menu, while elements like *RecyclerView* has been used for the dynamic list of notifications.

  To install the Android Support Library:
  - Start the Android SDK Manager (standalone or via Android Studio: Tool > Android > SDK Manager).
  - In the SDK Manager window, scroll to the end of the Packages list, find the Extras folder and, if necessary, expand to show its contents.
  - Select the Android Support Repository item.
  - Click the *Install packages...* button.
- **MPAndroidChart by Philipp Jahoda**: is a powerful and easy to use chart library for Android. It runs on API level 8 and upwards [95]. It permits to create 8 different chart types with a lot of features available to

interact with them. In the project, the MPAndroidChart has been used for the development of the Bar Chart in the Consumption section.
To install the MPAndroidChart library, the repository must be inserted in the Gradle file of the Android application, or the code can be downloaded directly from Git from the Android Terminal.

- **Google Gson**: is a Java library that can be used to convert Java Objects into their JSON representation. It can also be used in a reverse way, converting a JSON string to an equivalent Java object. Gson can work with arbitrary Java objects including pre-existing objects that a developer does not have source-code of [38]. In the application, it's used to parse message and response to/from the ESB and the Gamification Engine.
  To install the Gson library, the repository must be inserted in the Gradle file of the Android application, or the code can be downloaded directly from Git from the Android Terminal.
- **Jsoup**: is a Java library for working with real-world HTML. It provides a very convenient API for extracting and manipulating data, using the best of DOM, CSS, and jquery-like methods. It implements the WHATWG HTML5 specification, and parses HTML to the same DOM as modern browsers do [41]. The application does a large use of this library to parse html code coming from Reward description and styling.
  To install the Jsoup library, the repository must be inserted in the Gradle file of the Android application.
- **Glide**: is a fast and efficient open source media management and Figure loading framework for Android that wraps media decoding, memory and disk caching, and resource pooling into a simple and easy to use interface [69]. It allows the user to load Figures, video or gift in lazy loading, that is asynchronously with respect to other design elements of the page. In the application it is used to load users' avatar in both the homepage and the leaderboard page, in addition it's used to load rewards' Figures coming with the description text and the icon relative to the latest badge achieved by the user.
  To install the Glide library, the repository must be inserted in the Gradle file of the Android application. It depends on ProGuard (DexGuard) configuration and usage (application configuration file generated by Android Studio).
- **Glide Transformations**: is an Android transformation library providing a variety of Figure transformations for Glide [75]. In the application, it was used to create a rounded corner Figure for users' avatar.
  To install the Glide Transformation library, the repository must be inserted in the Gradle file of the Android application.
- **Joda-Time**: provides a quality replacement for the Java date and time classes. It extends the Calendar and Data management of Android providing further, more meaningful and more comprehensive features for Data and Time management [83]. It has been used in the Improve Yourself section for the displaying of the time spans of the water consumption readings according to the granularities. In particular, in the weekly visualization

of the consumptions, Joda-Time allows to create dynamically the current week start date to help the user to better understand which is the range of time of the current consumption.
To install Joda-Time, the full package with the source code should be downloaded from GitHub and manually imported. On Android, if all the features of such a library are not needed, the smaller part of them can be imported simply adding the reference of the package in the Gradle file of the project. SmartH2O only used a few part of the methods of the library, so the Gradle import was enough.

5.3 Components

The Application is a two-activities app (Main and Settings). An **Activity** is an application component that provides a screen with which users can interact in order to do something, such as take a photo, fill a form, etc. Each activity is given a window in which to draw its user interface (stored in a layout XML separate file and inflated into it).
An application usually consists of multiple activities that are loosely bound to each other. Typically, one activity in an application is specified as the "main" activity, which is presented to the user when launching the application for the first time. Each activity can then start another activity in order to perform different actions. Each time a new activity starts, the previous activity is stopped and a stack of activities is created, the "back stack" (used to navigate back to the previous activity). When a new activity starts, it is pushed onto the back stack and takes user focus [91]. In this application, there is the Main Activity and the Settings Activity, separated because of their actions: the first perform all the views associated to water consumption, tips and rewards a user can see. The second regard to general application settings. In order to navigate towards different sections of the application, Fragments are used instead.

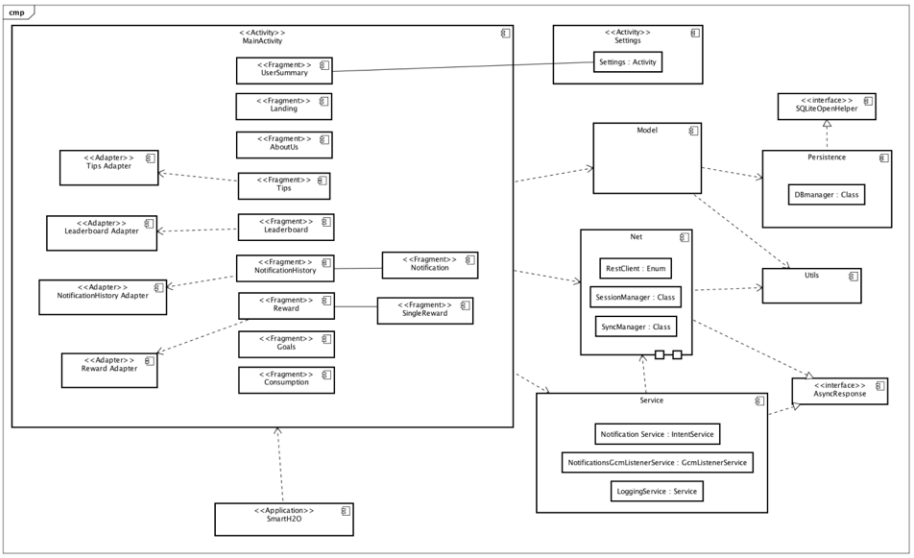

Figure 28: SmartH2O mobile application component diagram

A **Fragment** represents a behavior or a portion of user interface in an Activity. Multiple fragments can be combined in a single activity to build a multi-pane. A fragment can be thoughts as a modular section of an activity, which has its own lifecycle, receives its own input events, and which can be added or removed while the activity is running [92]. Android introduced fragments in Android 3.0 (API level 11), primarily to support more dynamic and flexible UI designs on large screens, such as tablets, where there's more space to combine and interchange UI components. Fragments allow such designs without the need to manage complex changes to the view hierarchy. By dividing the layout of an activity into fragments, the activity's appearance can be modified at runtime and can be preserved those changes in a back stack that's managed by the activity [92]. In SmartH2O application, the choice of fragments usage is due to the choice to build up a flexible and well performing application that could, in the future, be suitable to be used on tablets.

The **UserSummary** fragment is the homepage of the application, that is, the first page that is seen when a user – already logged – see when he/she starts the application. If a user is not logged yet, he will see the Landing Fragment, that is the fragment with the login-form UI. The hidden menu – that is, the *DrawerLayout* menu – displays a list of accessible fragments to let the user navigate through the app. For non-logged users, only the **About Us** Fragment is accessible, while all the other fragments are not. Once logged, the navigation menu is built with additional elements and all the other Fragments become accessible. **Settings** Activity is accessible from any other fragment of the Main Activity, providing the language choice. Also, once logged, the notification management is available.

As can be seen by Figure 28, the Main Activity and all its fragments are build

up thanks to other application's component useful to gain information and build objects used by the business logic of the app. Below, a list and a brief description of the usage of each component:

- **Model**: contains all the object the application instantiates in order to display and store correct information. Such objects are: tips, rewards, users, etc. Some of them are used to actually store data in the local app database, other just to help the application to display correctly information relative of a certain argument (such as badges, actions, etc.).
- **Persistence**: implements the logic to store object into the app's local memory database to retrieve useful information offline. It implements the lowest level logic to store information and data, made more general thanks to some model's methods implemented to further abstract such a logic.
- **Net**: is the component that actually performs all the RESTful HTTP GET/POST call to the ESB/Gamification Engine. It dialogues with the server part of the SmartH2O architecture in order to retrieve information and send useful data such as the user's app token for the notification management (see further sections) and the Usage Logger to study users' behavior using the application.
- **Service**: implement all the background services the application uses while running. There are three main services: The *NotificationService* implement the logic needed to register the application to the Google Cloud Messaging Server in order to receive notifications from the SmartH2O server part. The *NotificationGcmListenerService* is the background service that actually let the application to "listen" to incoming messages (notifications) to be displayed on the users' devices. The *LoggingService* is the service that perform all the logic needed to create and send the Usage Logger (see further sections for more details).
- **Utils**: is a component providing all the useful methods the app could use in order to perform better all the task it should do.
- **Application**: is the business logic required for Android OS to start the app.

5.4 Communication protocols

All requests of pull/push information to/from the server-side of the SmartH2O architecture (ESB) are done with HTTP GET/POST requests. In this section there will be made an overview of the main use cases implementing a direct communication between the mobile version of SmartH2O application (client application) to the server (ESB), to obtain all the data needed to build up the various sections of the app, or the Google Cloud Messaging (GCM) server to receive push notifications.

Sign-up
The first time a user installs the SmartH2O application and start it, if it's not registered yet, it must follow the registration steps in order to visualize his/her consumptions and other gamified data (Swiss plot only).

Table 23: Sign-up sequence

Use case:	1. Sign-up use case.
Note:	Fields in the registration form: username, password, email, SmartID, Zip code, answer to question "I know how much water I am consuming at home per month", user water consume estimation (in m^2), selection of the portal version (basic or advanced) and privacy policy acceptance.
Steps:	The user inserts his/her username, password and email. Then he is prompted to another page where he/she has to provide further information such as the SmartID and the Zip code, then enter responses to some questions. At the end, he/she must read and accept the privacy policy. The Authentication Gateway verifies if the user created already exists. If the user doesn't exist, the registration phase can continue. The ESB verifies the Utility Code (SmartID) provided by the user. If the Utility Code is verified, the user is actually created and saved. The user can login and his/her information are stored in the application local memory.

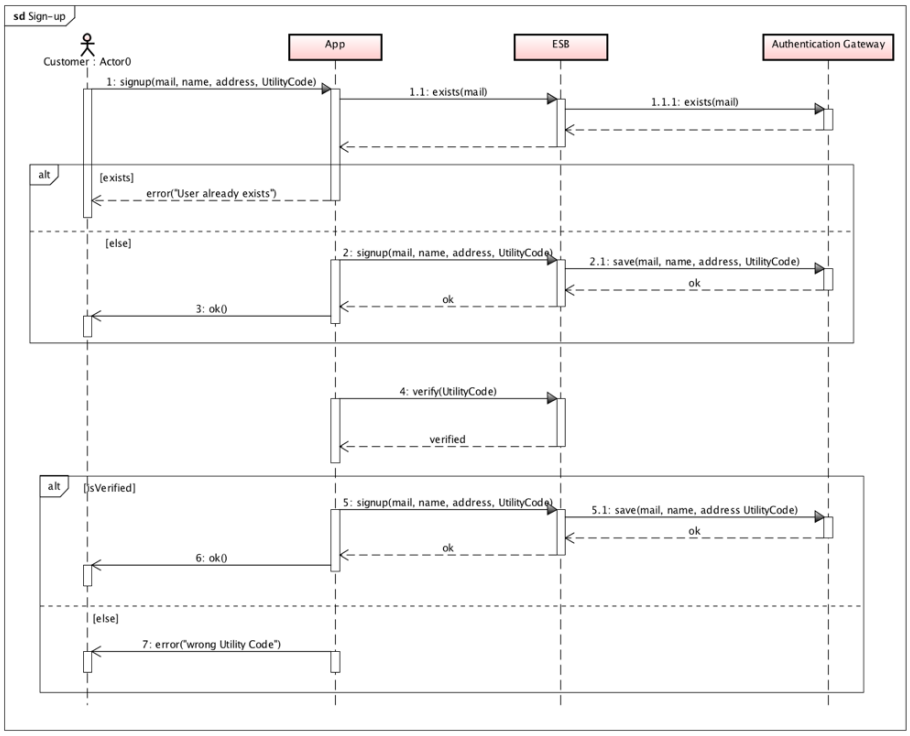

Figure 29: Sign-up sequence diagram

Sign-in

The first time a user installs the SmartH2O application and start it, it must login in order to see his/her personal water consumption information.

Table 24: Sign-in sequence

Use case:	2. Sign-in use case.
Note:	Fields in the login form: username and password.
Steps:	The Authentication Gateway verifies if the information provided by the user are correct and if the user with such username and password exists. If it's the case, replies with a ticket. The app uses the ticket to request a Service Ticket to the Authentication Gateway. The Authentication Gateway provides such ticket and the app validates it. If the procedure success, the handshake finishes. The user can login and his/her information are stored in the application local memory.

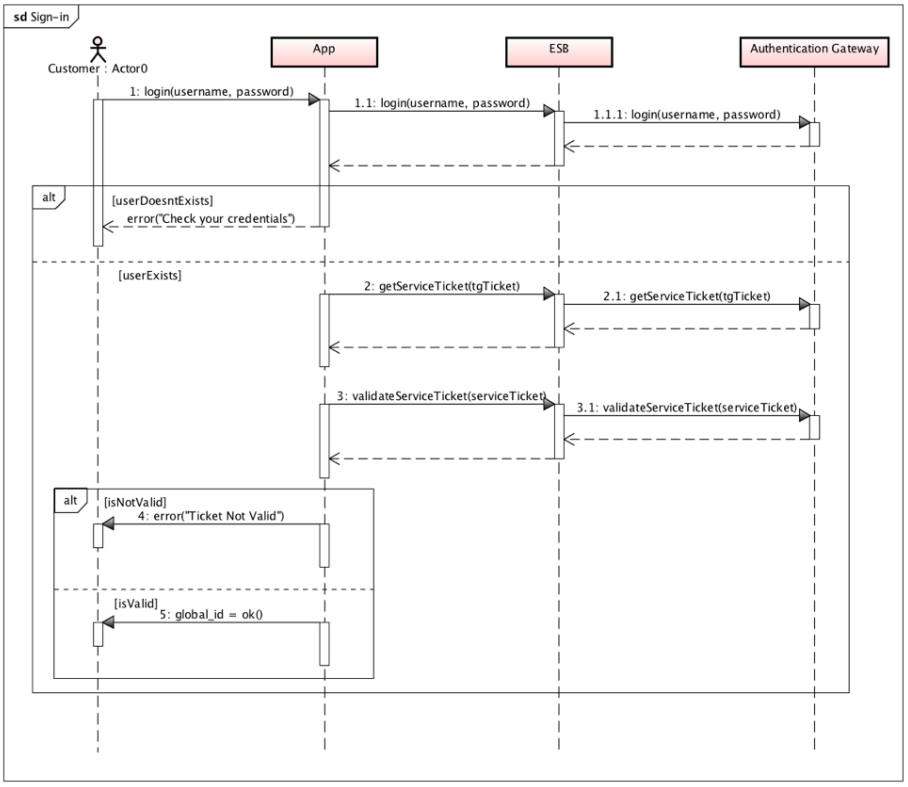

Figure 30: Sign-in sequence diagram

Displaying Homepage of the app

The Homepage of the application (the main activity, as it's called in Android), is made by the UserSummary Fragment, that is done by several sections, all displaying some user's specific information such as: the consumptions, his/her ranking in the leaderboard, his/her badge achieved and the suggested actions. In order to display correctly all those information, several steps are required.

Table 25: Homepage sequence

Use case:	4. Visual exploration of aggregated water consumption 7. Suggested actions and exploring results (Gamification part) 10. Leaderboard (Gamification part)
Note:	All the steps required to build up the homepage (main activity) screen are synchronous. Other tasks are triggered but are done in background in an asynchronous way and, in case of failure, don't preclude the page to be correctly loaded.
Steps:	The user launches the application. The app check whether it has received the Registration token or not. If not, it asks for registration to the GCM. The GCM processes the request and send the Registration Token to the client app. The app sends the Registration Token to the serve (ESB) that saves it in the SmartH2O DB. The app subscribes to topics using its Registration Token.

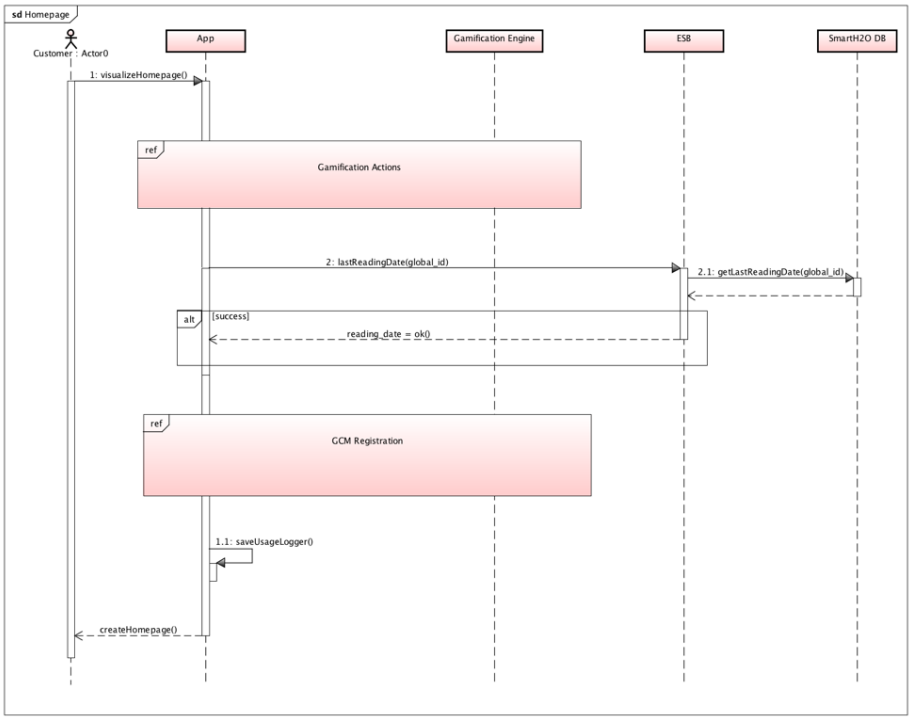

Figure 31: Homepage display sequence diagram

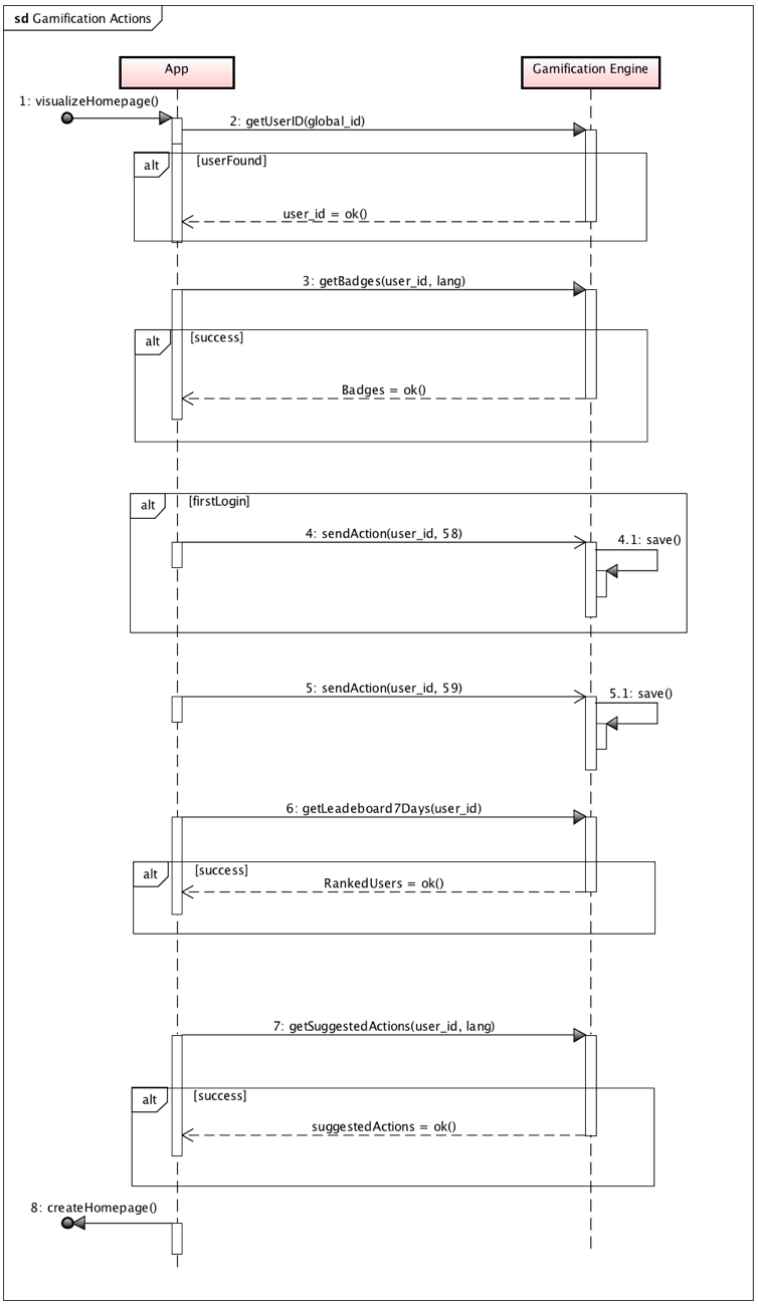

Figure 32: Gamification part sequence diagram

Register user's action using the application
All the actions performed by the user using the application (selection of a goal,

navigation to a specific page, visualization of consumptions w.r.t. a specific granularity, etc.) should be registered and sent periodically to the Gamification Engine in order to save and, later, study the users' behavior while using the application. It's important to improve the motivation mechanisms used to incentivize the user on the water consumption and increase is awareness on this problem.

Table 26: Usage Logger sequence

Use case:	11. Usage Logger
Note:	All the meaningful actions performed by the user while using the application are stored in an object called Loggable Event. The sum of all those objects is a Usage Logger.
Steps:	The user or the systems kill the application. While performing the stopping procedure, the app sends to the Gamification Engine the Usage Logger created aggregating all the Loggable Events registered during the last session the user has spent using the app.

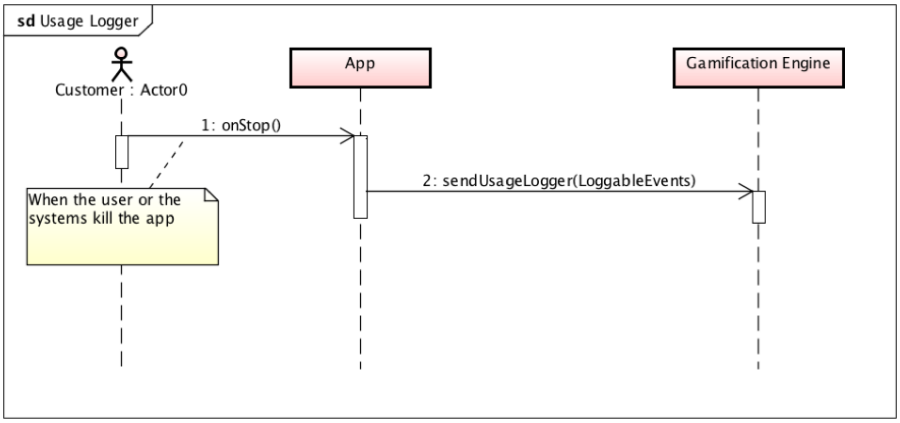

Figure 33: Usage Logger sequence diagram

Enable the reception of Push Notification
The application must register to the Google Cloud Messaging Server in order to receive push notifications (see next chapter for further details). To do so, the application must request a Registration Token to send to the application server (ESB) to receive such notifications. Notifications can be: direct notifications or topic notifications. Direct notifications are sent by the server (ESB) directly to one user's app towards the registration token as receiver address. Topic notifications are send to a specific channel and are received to all the applications that are registered to that specific topic. Using the Registration Token, the app can register to such topic, specific of the application domain.

Table 27: Push Notifications sequence

Use case:	6. Getting Push Notifications
Note:	The operation is done in background and uses the Client ID and the Application ID to receive the Registration Token (see next chapter for more details). Then the Token is used to register to topic notifications.
Steps:	The user launches the application. The app check whether it has received the Registration token or not. If not, it asks for registration to the GCM. The GCM processes the request and send the Registration Token to the client app. The app sends the Registration Token to the serve (ESB) that saves it in the SmartH2O DB. The app subscribes to topics using its Registration Token.

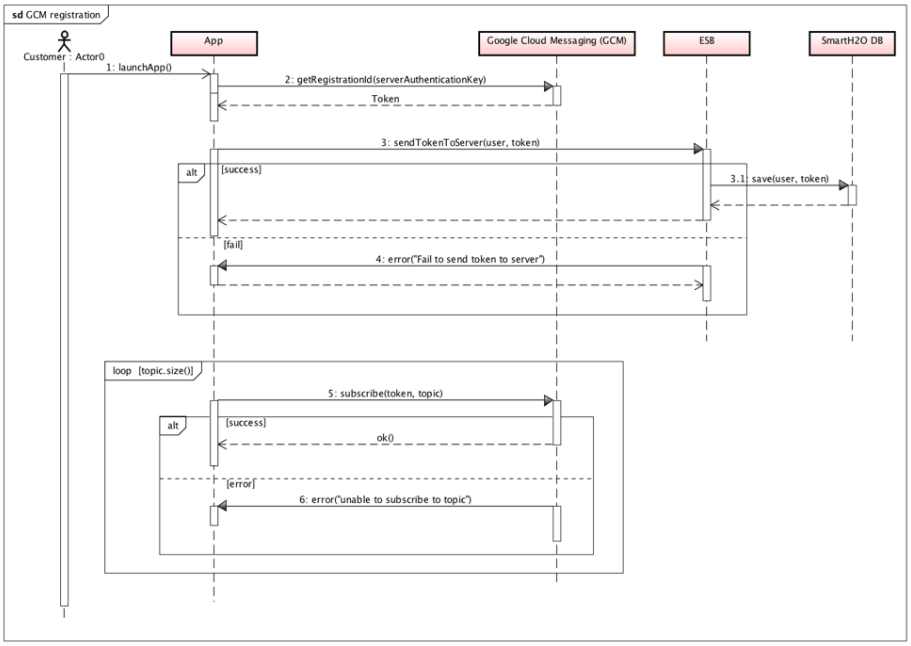

Figure 34: Registration with the GCM sequence diagram

In next section there will be a detailed explanation of all the steps required in order to enable push notification reception on the application.

Push Notifications: Google Cloud Messaging

Google Cloud Messaging (GCM) is a free service that enables developers to send messages between servers and client apps. This includes downstream messages

from servers to client apps, and upstream messages from client apps to servers (if XMPP is implemented) [81].

Architecture

The implementation of GCM's mechanism include a GCM Connection Server, a client app (that is, the mobile version of SmartH2O) and a server part (That is the ESB and the Gamification Engine).

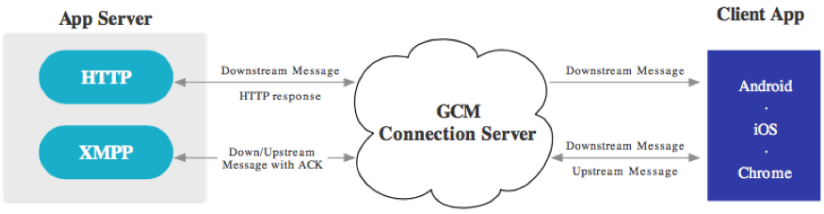

Figure 35: GCM architectural overview

In order to create an architecture suitable to send/receive push notification on SmartH2O mobile application, the two main concepts at the base of the GCM architecture must be implemented:

- **Components**: the entities that play a primary role in GCM. They are:
  - **Google GCM Connection Servers** accept downstream messages from the server-side and send them to a client app. It's provided by Google, allowing connections toward HTTP or XMPP.
  - The **Server-side** (**ESB**) is where has been implemented the HTTP protocol to communicate with the GCM connection server(s). ESB send downstream messages to a GCM connection server; the connection server enqueuers and stores the message, and then sends it to the client app (SmartH2O mobile version).
  - The **Client App** (**mobile version of SmartH2O app**, in this case) is a GCM-enabled client app. To receive and send GCM messages, this app must register with GCM and get a unique identifier called a *registration token* (mechanics seen in previous chapter).
- **Credentials**: The IDs and tokens that are used in GCM to ensure that all parties have been authenticated, and that the message is going to the correct place. They are:
  - **Sender ID**: it's a unique numerical value created during the configuration of the API project form the Google Developer Console.
  - **Server key**: it's a key saved on server-side (ESB) that gives the server authorized access to Google services. In HTTP, the server key is included in the header of POST requests that send messages.
  - **Application ID**: it's the client app that is registering to receive messages. In Android, it is the package name from the app's manifest.
  - **Registration token**: it's an ID given the app by the GCM Connec-

tion Server(s) to that allows the first to receive messages.
First of all, the application should be registered to the **Google Play Developer Console** (*https://play.google.com/apps/publish)* using a developer account – that is a Google account where has been bought a developer license. After setting up the name of the application and other parameters, in the Services & API settings there is a panel where a **Sender ID** can be linked to the application. The procedure generates a JSON file that should be put in the root of the application (in the app folder, for Android) and that contains all the information that the GCM will use to set up the connection between the server (ESB) and the client app (mobile version of SmartH2O application). In the same section, a **Server Key** is generated, which should be stored server-side.
At first application startup, the app should check whether the device on which it is installed is allowed to access to Google Play services. If it is the case, the app starts the background task to interact with the GCM to obtain the **Registration Token**. This procedure is repeated several times in case of failure. If success, the token is stored in the local memory of the application, sent to the server (ESB) – as has been seen in the previous chapters – and the procedure for the subscription to specific app topics is performed. In case of failure, nothing happens and the procedure is repeated at next startup.

Message formats

GCM server allow two different connection protocols and different message types. In this scenario, HTTP is chosen as connection protocol, allowing the server (ESB) to send JSON message towards an HTTP POST request. This is a synchronous mechanism, that is the ESB send messages as HTTP POST requests to the GCM and wait for a response. This blocks the sender from sending another message until the response is received.
In the messages sent from the ESB to the SmartH2O app, there are two parts: *HTTP header part* and *HTTP body part*. In the body part there could be arbitrary data. However, some fields are required to a correct message exchange between the two players. In details, two types of push notification (and then, messages) can be sent: *direct notifications* and *topic notifications*. Direct notification must implement a "*to*" field that is the token of the target application. In addition, a "*data*" field (or "*notification*" field) can contain further information, completely customizable. The target application (a SmartH2O instance installed on a user's device) must take care of the message, handling such information. An example of JSON-formatted direct notification is [81]:

```
{
        "to" : "bk3RNwTe3H0:CI2k_HHwgIpoDKCIZvvDMExUdFQ3P1...",
        "notification" : {
        "body" : "Notification message",
        "title" : "Notification Title",
        "icon" : "myIcon"
        }
}
```

Topic notification, instead, don't point to a single user, but to a bulk system of app that are registered to a specific topic. Registering to a topic is a client-app issue (see previous chapter). The mandatory "*to*" field will include the name of the topic the application is subscribed for. Again, a "*data*" field could contain further information the app-client must take care of. An example of JSON-formatted topic notification is [81]:

```
{
        "to": "/topics/test",
        "data": {
        "title" : "This is a topic Notification Title! ",
        "message" : "This is a topic Message!",
        "icon" : "myIcon"
        }
}
```

The POST request to send such notification to client-app must be implemented server-side, with the following parameters in the header part [81]:

- **POST URL**: *https://gcm-http.googleapis.com/gcm/send*
- **Content-Type**: application/json
- **Authorization**: key=AIzaSyZ-1u...0GBYzPu7Udno5aA

Group Notifications

A user – seen as a single account – can have several devices, or at least could login from different stations or let other member of his family to use the application with the same family account. A direct notification cannot rely only on a user's device token but should be able to send the same notification to the same user account still reaching all devices where such account is active. Then, instead of sending messages to a single user token, a group token is used instead. Using group messages, the ESB is able to send the same notification to all the instances of an application linked to a specific account running on different devices. The server part of the architecture should create and manage all the message groups using special configuration messages having an "*operation*" field relative to the action that should be performed (creation, addition or removal of a token from the group).
In order to create a group for a user's account, the ESB must create such a group as the first token for such customer is sent to the server. To do so, the ESB itself performs a POST request to *https://android.googleapis.com/gcm/notification* specifying as header parameters:

- Content-type
- Authorization (server) key
- Project id, that is the application numerical id that can be found in the configuration JSON file stored in the root of the application (the same for all instances).

Then, in the body part, there must be: the operation "*create*", the notification key name (typically the username), that should be unique for each group, and a JSON-Array with at least one token generated by the user's device. If the

operation succeeded, the GCM replies with a *notification key* that should be used instead of the simple user's token to send notifications.
Every time the user logs in another device, another token is created for such account and sent to the server. If the notification group for the customer is already set-up, then the new token must be added to such a group, performing another POST request with the operation "*add*" followed by the group unique name, the notification key and the new token of the user. If a token should be, instead, removed from the group – for example when a user performs a logout from a device – the same POST request with operation "*remove*" is performed. If a user uninstalls the application, the token is automatically canceled from the GCM and also from the group where it belonged.

Response format

When the server sends a notification, the GCM server can reply with two kind of messages: success message or failure message. In case of success message, the GCM specifies the *message_id*, while causes of failed messages are referenced in the error field (e.g., "*TopicsMessageRateExceeded*") [81].

Stop receiving notifications

In the SmartH2O applications, the Settings panel has been introduced to let the user unsubscribe from some types of notification (or all). To unsubscribe from a topic notification, a call to the function *unsubscribe(token, topic)* is enough. On the other hand, to stop receiving direct notification, a Boolean variable representing the wish to receive such notification or not, is saved in the local memory of the application. If a direct notification arrives and the relative variable is set to false, nothing is displayed on the user's device.

Publish the app on Google Play Store

After registering the application on the Google Developer Console with a developer account (already done in order to create and setup the Google Cloud Messaging APIs), there are two main steps that must be accomplished in order to publish the application on the Google Play Store:

- **Preparing the application for release**: that is building a release version of the application, which users can download and install on their Android-powered devices. In detail: with Android Studio, a release-version of the APK (application package) of the app must be created, signed with the developer key, that is the key of the developer himself [93]. The Android system requires that each installed application be digitally signed with a certificate. The Android system uses the certificate as a mean of identifying the author of an application and establishing trust relationships between applications. Such a certificate does not need to be signed by a certificate authority; the Android system allows the developer to sign the applications with a self-signed certificate. The only difference

with the debug APK is, in the end, that this release-ready APK file is signed with such a certificate (plus, it is optimized with other tools). In fact, the release-ready package contains the same components as the debug APK file — compiled source code, resources, manifest file, and so on — and it is built using the same build tools.

- **Releasing the application to users**: this is the real publishing phase, where the app is released and is publicized, sold, and distributed to users [93].

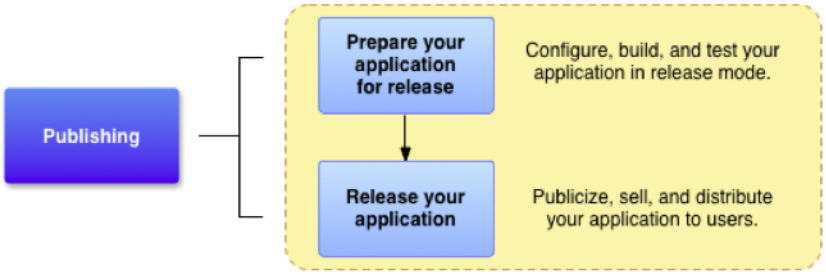

Figure 36: First two steps of the publishing phase

At a minimum all the Log calls and the *android:debuggable* attribute in the manifest file should be removed. Also, during the publishing phase information such as the *android:versionCode* and *android:versionName* attributes, which are located in the <manifest> element, should be provided.
After those steps, the release version of the app can be published on the Google Play Store.
Releasing an application on Google Play is a simple process that involves three basic steps:

- **Preparing promotional materials**: that is, the creation of promotional materials for your application, such as screenshots, videos, graphics, and promotional text (meaningful description of the app).
- **Configuring options and uploading assets**: Google Play allows to target an application to a worldwide pool of users and devices. By configuring various Google Play settings, the countries to reach, the listing languages to use, and the price to charge in each country can be chosen. Other listing details can be configured, such as the application type, category, and content rating. After that, promotional materials previously prepared can be uploaded and the application can be published as a draft (unpublished) application.
- **Publishing the release version of the application**: by clicking on Publish in the developer console and within minutes, the application will be live and available for download around the world.
- **Other options**: in SmartH2O case, the application was not meant to be available from the beginning to all the users. Google Play allows to publish an application with restrictions, such as alpha or beta testing restrictions. SmartH2O mobile application, thus, was published in alpha mode testing

so that only a restricted and authorized pool of users can access, download and use it.

Open access to the source code

The full source code of the mobile version of SmartH2O application can be found in GitLab by this URL: *https://gitlab.com/wds-co/SmartH2O-PortalApp.git* and can be downloaded and tested on every Android devices (OS >= 4.x Ice Cream Sandwich). The Google Play URL to download the apk is: *https://play.google.com/store/apps/details?id=it.polimi.sh2o.portalapp*. The application is developed to work on *Aguas De Valencia* (the Spanish water utility company) servers, dealing with their customers' profile information to retrieve water consumption data. To try the application using *Politecnico di Milano*'s servers and services, few parameters adjustments should be done. The **Rest-Client** component, present in the net section of the application, deals with the communication between the app itself and the services (as has been seen in previous sections). In this component there are all the parameters used to invoke such services. To try the application, a user must switch from the *Aguas De Valencia* parameters to the *PoliCloud* (Politecnico's cloud servers) parameters, commenting the first ones and de-commenting the latter ones.

E.g.: convert

String SCHEME = "https://www.aguasdevalencia.es:8443/SmartH2O/";

to

String SCHEME = "http://89.121.250.90:8083/SmartH2O/";

6 Evaluation of the SmartH20 mobile application

In this chapter, results obtained by the use, in both the Swiss and Spanish pilots, of the SmartH2O application by real users will be provided. Due to the restricted time, the mobile version of the application was not released to the general public yet at the time of this thesis, for that reason results from the web portal will be reported as evidence of the impact of the application. In addition, two questionnaires have been provided to the alpha testers of the mobile app in both pilots, providing a first feedback of the use of the mobile application, letting possible a first comparison between the two versions of SmartH2O: mobile and web portal.

6.1 Methodology

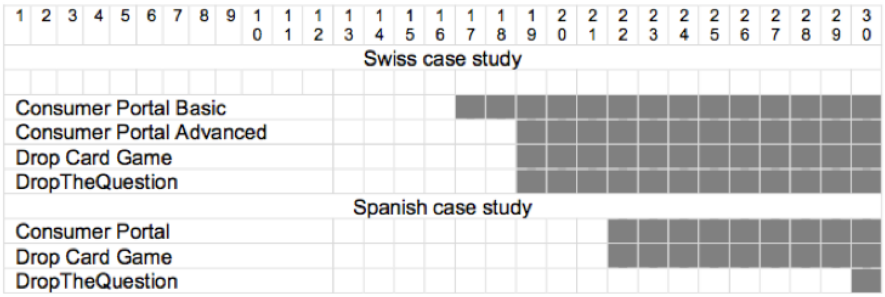

Figure 37: Release calendar for both pilots [89]

A set of trials, for each study case, has been defined as part of a validation methodology. A trial is a period of time where users use the application and data about their behavior is collected. Four trials were planned that were aligned with releases of the SmartH2O web platform. Figure 37 refers to the release dates of the various version of the portal in both pilots. On the top are visualized the months of the project. Month 1 is March 2015 [89]. During the trial period water consumption was continuously monitored, whilst social awareness was assessed after each trial period. The objectives of the feedback collection require a quantitative approach that allows the project to relate measures of social awareness and technology acceptance to the smart metered water consumption measurements. In order to do that, questionnaires have been developed to be answer by the users of the platform after each trial period. The next subchapters will explain the construction of such questionnaires and the results of the responses collected. In addition, a comparison with the results of the new questionnaires, given to alpha testers, designed for the evaluation of the mobile app will be done.

6.1.2 Questionnaire construction

Questionnaires were used to elicit the users' opinions about the SmartH2O portal and the employed incentive model in particular. Questionnaires were distributed to users in both the Spanish and the Swiss pilots.
Technology acceptance was measured on the level of the application (web first and mobile thanks to alpha testers) as a whole and on the level of individual use cases [89]:

- Awareness with respect to water consumption
  In subchapter 2.4.1, the psychological factors affecting water consumption – called determinants – were discussed in detail. This led to the efficiency of the social awareness construct into measurable determinants of water consumption. This questionnaire addresses those psychological determinants:
  - Attitudes towards water conservation (bipolar scales; e.g. good-bad).
  - Beliefs with respect to water conservation (four-point Likert scale [39], e.g. "Drinkable water is an unlimited resource.").
  - Water conservation intention (two (Spain) or three (Switzerland) five-point Likert scale; e.g. "I expect I will engage in everyday actions to save water in the next six months.") (Difference is due to language specificities. In Spanish, intention items with 'I want' and 'I intend' cannot be distinguished).
  - Subjective norm (three five-point Likert scale [39];; e.g. "It is expected of me that I save water.).
  - Perceived behavioral control (one five-point Likert scale [39];; "I am confident that I could save water.").
  - Technology acceptance indicators on application level.
- Technology acceptance was measured based on the *UTAUT* model [28]. The following constructs were measured: The following constructs were measured:
  - Performance expectancy (2 five-point Likert scale items).
  - Effort expectancy (4 five-point Likert scale items).
  - Attitude towards technology (4 five-point Likert scale items).

  Additionally, hedonic (HQ) and pragmatic quality (PQ) were measured to assess the hedonic and utilitarian value users derive from using the SmartH2O platform (both web and mobile version). The *AttrakDiff2* questionnaire was used for this purpose.
- Technology acceptance on use case level
  For each of the portal's – and thus the mobile – features, questions were asked to assess the user-based performance indicators according to each use case, as seen in subchapter 4.1.3. Five-point Likert items were used. To summarize, the following topics were addressed:
  - Perceived usefulness.
  - Ease of use.
  - Joy of use.
  - Comprehension.

– Effect of the gamification elements on the motivation to save water and to use the SmartH2O portal.

All the cited questionnaires can be seen in Appendix A.

6.2 Environment set-up

In this subsection, there will be an overview of the settings of the two pilots: the Swiss and the Spanish one.

6.2.1 Swiss Study case setting

As has been said in subchapter 3.2, this study case is made in collaboration with the SES (Società Elettrica Sopracenerina) in Terre di Pedemonte, near Locarno in the Swiss Canton of Ticino. The location is a small municipality with 1206 inhabitants, distributed in 3 districts: Tegna, Verscio and Cavigliano. As the population of Terre di Pedemonte could not be assumed to be representative of the whole Canton Ticino, the SmartH2O project issued a questionnaire to 70000 out of the 158647 households which are registered in the whole Canton [85].
A total of 462 households answered to the questionnaire, and a number of statistics were extracted. It was assumed that the sample described correctly the general profile of users interested in water awareness and in increasing their water efficiency.
Figure 38 shows the results from the questionnaire, in details are users demographic: in the gender graph, on the left, can be seen that the male population dominate over the female one. On the right, the age distribution graph shows that the majority of the people is over 41 years old.

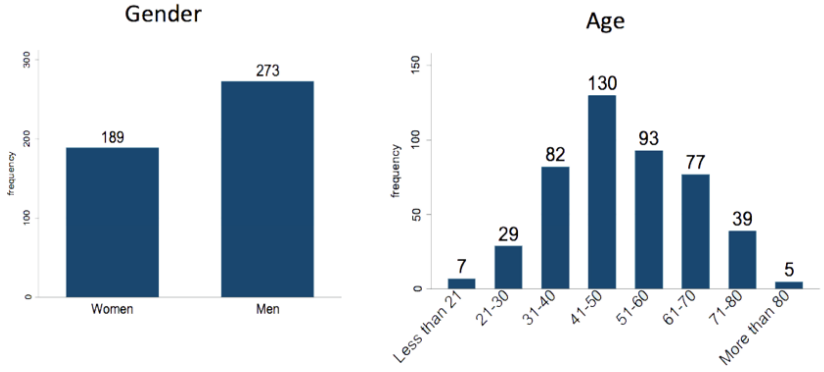

Figure 38: Age and Gender statistics of the Switzerland study case

The statistics include information about the household configuration like the number of bathrooms per household, the number of installed bathtubs, shower stalls and taps (Figure 39), as well as on the frequency and duration of shower/bath usage (Figure 40). Statistics on appliances and other usage prefer-

ences were also reported, like the presence of washing machine and dishwasher (Figure 41). Finally, statistics on the presence of a garden, plants or swimming pools per household and the related water usage actions were reported (Figure 42 and Figure 43). This data provided a baseline description of the users in Canton Ticino [85].

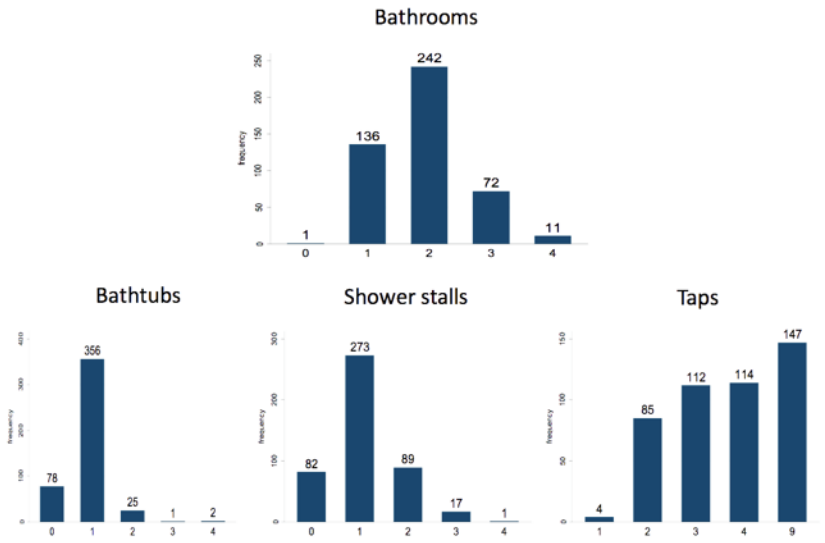

Figure 39: Household characteristics statistics: Top: number of bathrooms, bottom left: the number of bathtubs, bottom center: the number of shower stalls, bottom right: the number of tap [85].

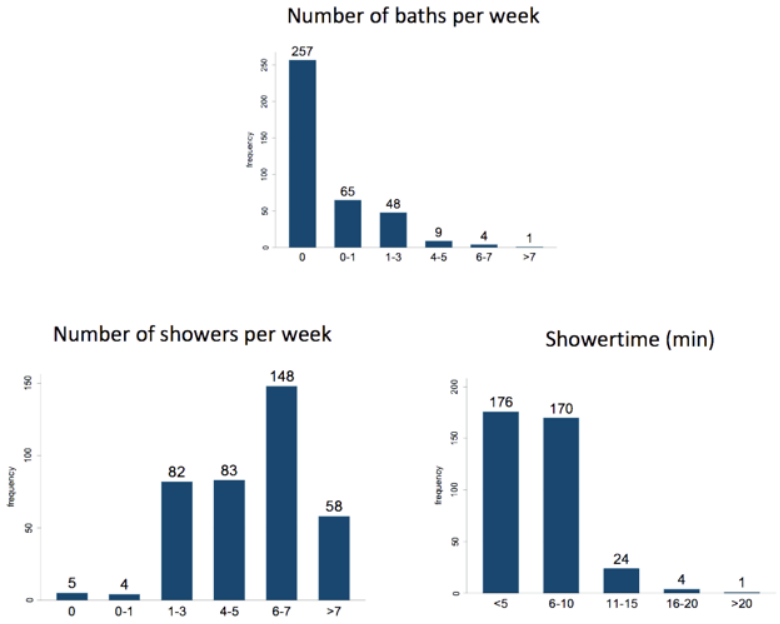

Figure 40: Statistics of frequency and duration of the shower/bath usage: Top: number the bath per week, bottom left: number of showers per week, bottom right: number average shower time in minutes [85].

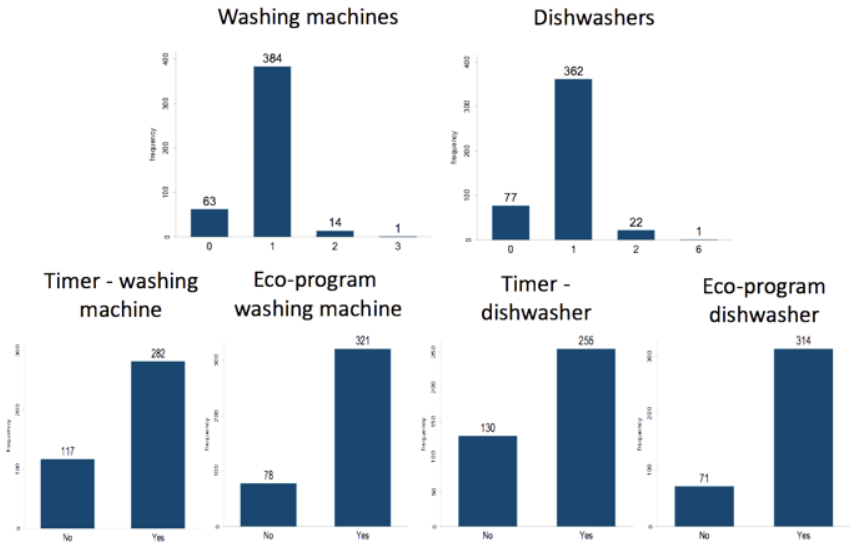

Figure 41: Statistics on appliances and usage: Top center: number of washing machines, top right: number of dishwashers, bottom left: timer on washing machine, bottom center left: eco-program washing machine, bottom center right: timer on dishwasher, bottom right: eco-program on dishwasher [85].

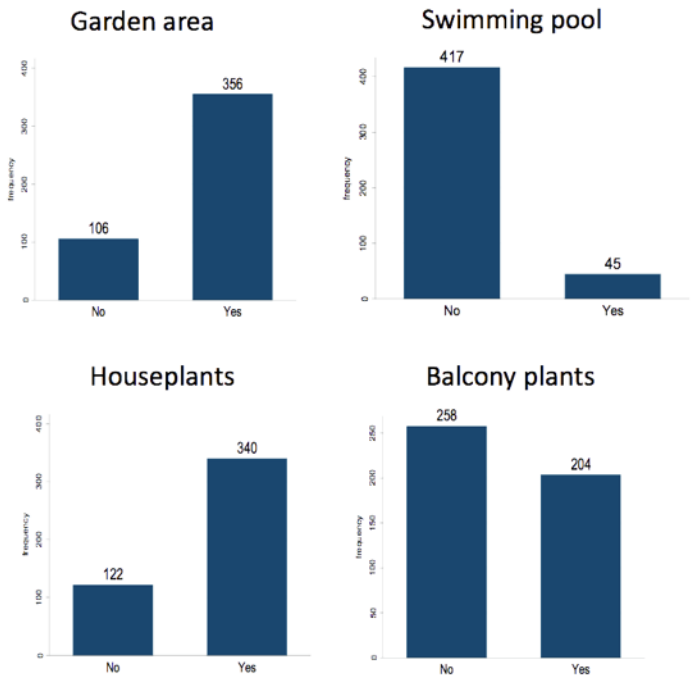

Figure 42: Statistics of gardening and pool: Top left: presence of Garden Area, top right: presence of pool, bottom left: houseplants, bottom right: balcony plants [85].

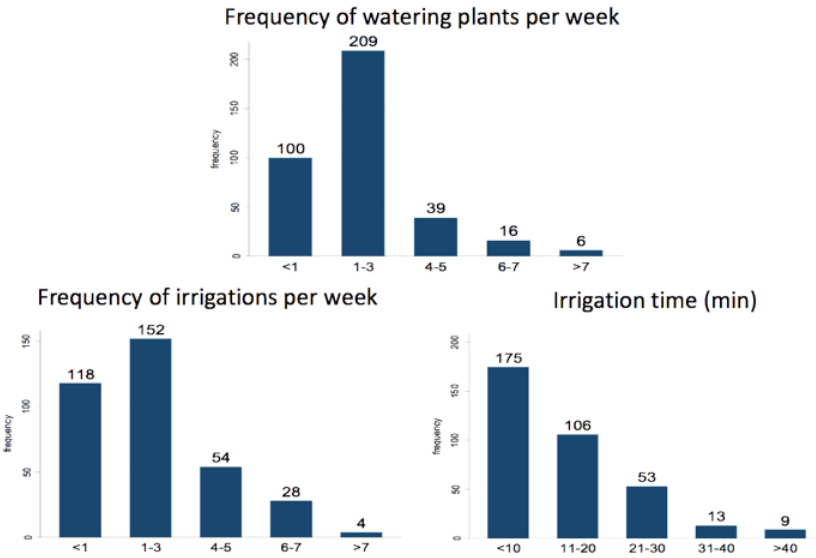

Figure 43: Statistics of water usage due to presences of plants: Top right: Watering frequency per week, bottom left: irrigation frequency per week, bottom right: average irrigation time in minutes [85].

6.2.1 Spanish Study case setting

As has been said in subchapter 3.2, this study case is made in collaboration with the EMIVASA (Empresa Mixta Valenciana de Aguas, S.A.) and AVSA (Aguas de Valencia Group), based in Valencia. With a population of 786189 inhabitants, Valencia is the third largest city in Spain (in 2015) and is the capital of the Valencia Autonomous Region (Comunitat Valenciana).
The water supply of the city is done completely by partner companies of the SmartH2O project that are part of a larger corporation that handles all the water related services like the water provisioning, the sewer network maintenance, the wastewater treatment, etc.
The deployment of smart meters in the city is widely spread with a total of 367505 smart meters from which 288229 (in December 2015) are connected to a fixed network and provide hourly readings.
The characterization of the user population is based on the data published by the Spanish Institute of Statistics (Instituto Nacional de Estadìstica, INE) and the Valencian Institute of Statistic (Instituto Valenciano de Estadìstica, IVE). Those records refer to the city of Valencia itself and to the whole Valencian province (which mainly corresponds to the city of Valencia and its metropolitan area).
The Figure 42 show the demographics by gender and group in age ranges, it can be observed that, similar to the Switzerland case, the number of male people is

a little bigger that the female number, and that the population over 40 years old is dominant, but in this case the population under 40 is also considerably larger.

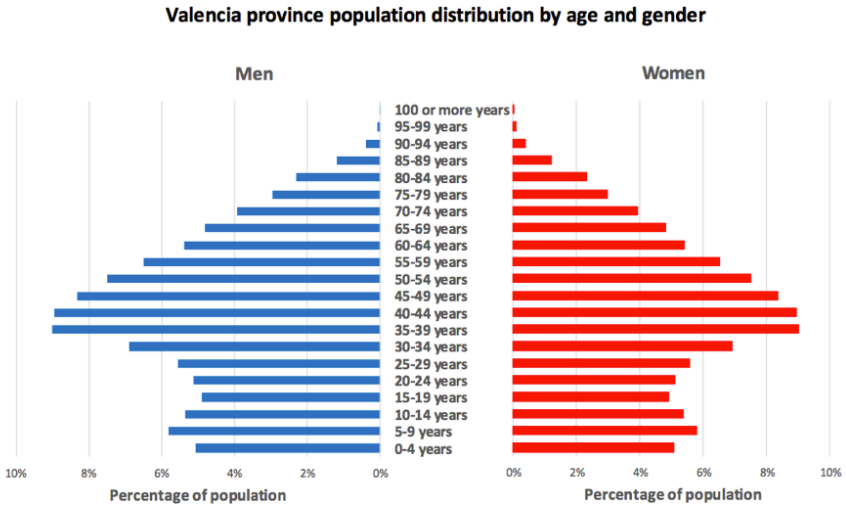

Figure 44: Age and Gender statistics of the Spain study case [85].

The two graphs below show the distribution of the population by education, working sector and income (respectively, Figure 43, 43 and 44), from them it can be observed that the majority of women have completed the university's studies, on the other hand the biggest number of men have left the education path after the middle school. Then it can be seen that the majority of the population is employed in the services sector, especially women, and that the population with income higher than 14000 euros per year is the biggest segment .

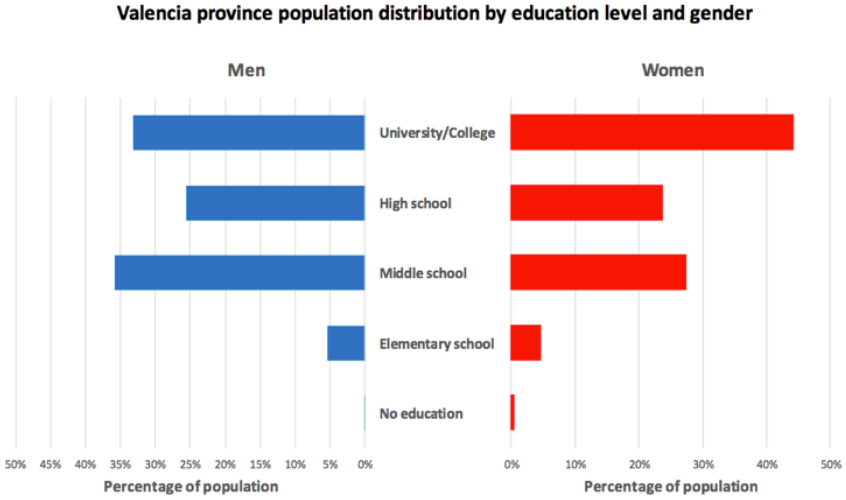

Figure 45: Population per education level and gender in the Valencia province [85]

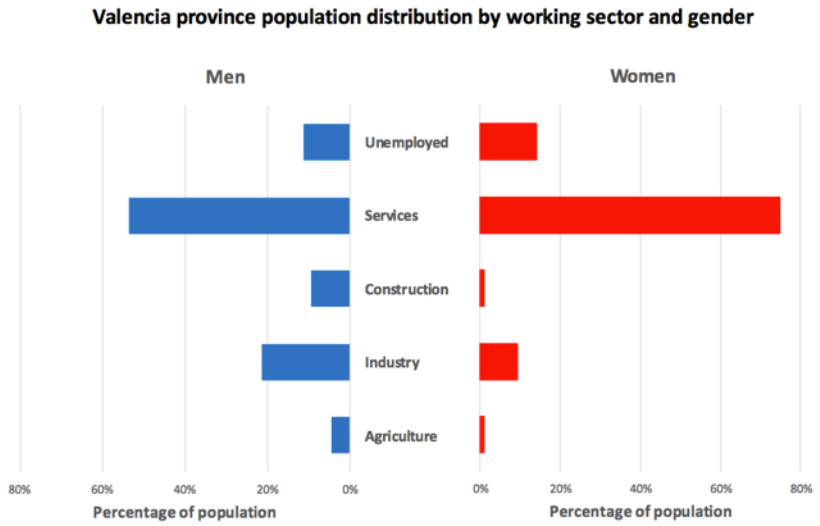

Figure 46: Statistics of employment sector by gender [85].

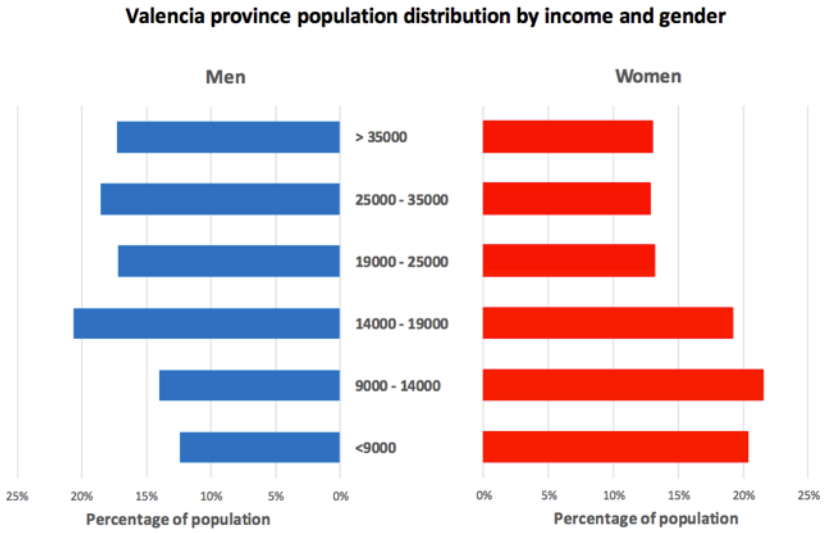

Figure 47: Statistics of annual income by gender [85].

6.3 Usage Data Analysis and Questionnaires results of the web Portal

In this chapter an evaluation of the questionnaires about the web portal are reported, for both pilots. Then a first usage data analysis has been done to confirm, or not, the expectation on the behavior of users reported by the ques-

tionnaires.

6.3.1 Spanish use case

The Spanish case study targets a significantly larger potential population in the Valencia metropolitan area. At the time of writing 389 have registered for the portal. From the SmartH2O user base in Valencia, 32 participants have filled out the questionnaire, which means a 9% response rate. This 9% response rate should be considered high, since other similar online surveys can yield rates as low as 1% to 3%.

6.3.1.1 Questionnaire results

This subchapter reports the questionnaire results, in terms of technology acceptance and the effectiveness of the incentive model, as perceived by the users in the Spanish case study.

Technology acceptance (Spanish pilot)

From the UTAUT framework [28], effort expectancy, performance expectancy, and attitude towards technology were measured. In Figure 46 "effort expectancy" results are displayed, as a measure of the perceived ease of use. Then, users had a positive attitude towards the SmartH2O web portal, in fact they considered the portal to make saving water more interesting. This result suggest that the motivational affordances included in the web portal have been effective to raise interest in water conservation, the extent that this can be judged from self-reported measures. User behavior results shown in the next subchapter 6.3.1.2 will be able to support this preliminary conclusion.

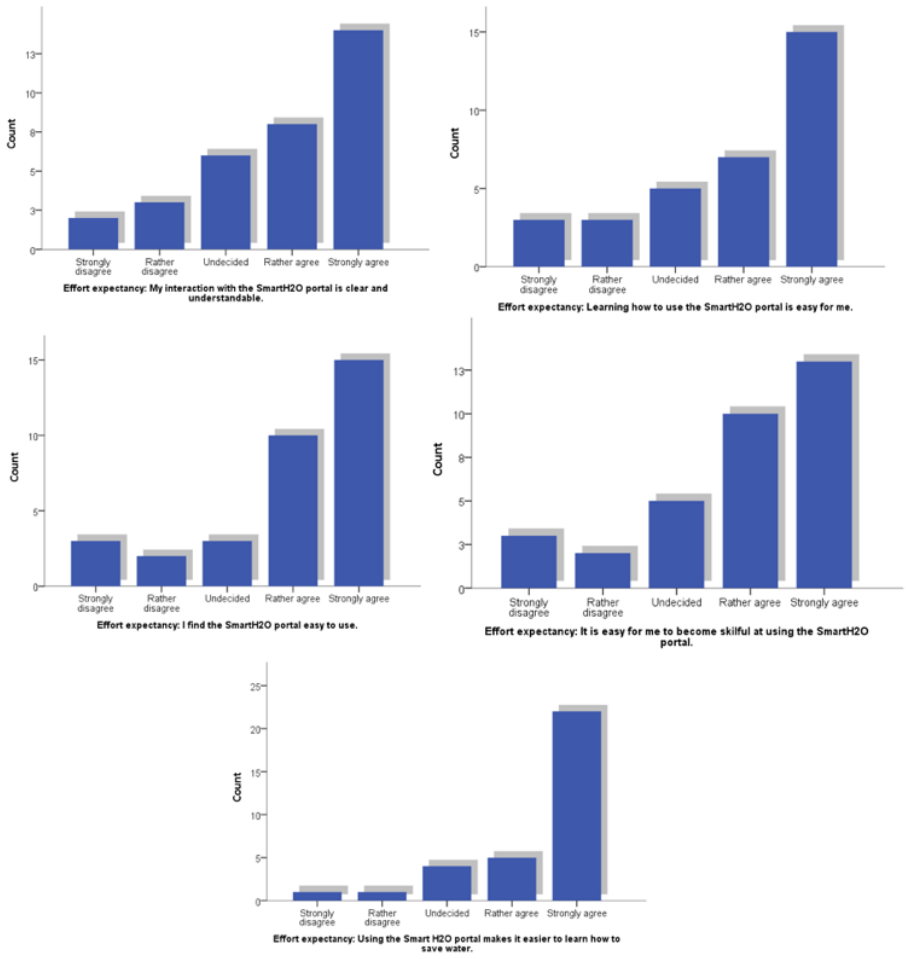

Figure 48: UTAUT: Effort expectancy item results

The UTAUT [28] results on effort expectancy, performance expectancy, and attitude towards technology suggest that the SmartH2O portal is considered ease to use and useful, with users liking the usage of the portal [89].

Hedonic and Pragmatic quality (Spanish pilot)

Hedonic and pragmatic quality was measured using the *AttrakDiff2* questionnaire [29], in which hedonic quality (stimulation) and pragmatic quality were measured. The results are displayed below (Figure 49) [89].

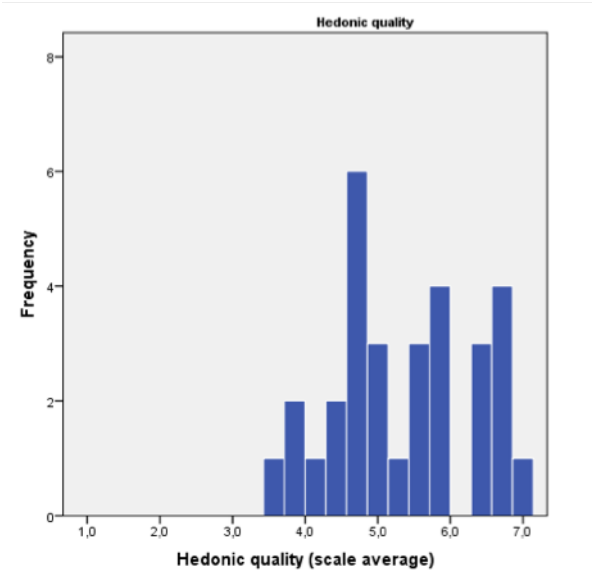

Figure 49: Hedonic quality (stimulation) results [89].

Hedonic quality (stimulation) received on average a score of 5.4 on a scale 1-7, which is considered as stimulating. The innovativeness and originality of the SmartH2O portal were highly rated, and the users found the portal stimulating to use, according to those results. This is positive, as this was the primary purpose behind the incentive model: to make saving water and engaging with water consumption information not only useful, but also stimulating and fun to do.

The pragmatic quality results are displayed below (Figure 50).

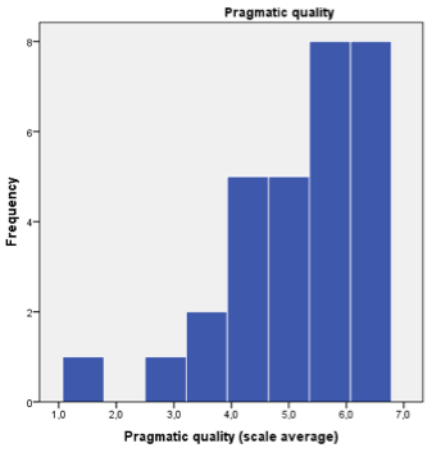

Figure 50: Pragmatic quality results [89].

Pragmatic quality scores are still rather positive, even if on average slightly lower than hedonic quality. The balance between pragmatic quality and hedonic quality suggests that users are both stimulated by the innovative nature of the portal, and able to derive utilitarian value from it.
These results are encouraging since they represent attitudes of regular customers of Aguas de Valencia to which the gamified SmartH2O platform has been proposed as a replacement for the common Virtual Office of their water utility. These first results suggest that the gamified SmartH2O portal can both well stimulate users at the hedonic level (important to motivate acceptance and continuous usage) and support the pragmatic purpose for which they use the water consumption data and saving tips [89].

Gamification elements as incentives (Spanish pilot)
The graphs in the next figure (Figure 51) show the result of the analysis of all indicated incentive model elements (gamification elements) in subchapter 6.2. It can be seen that them could offer a strong motivational affordance to the users. The small standard deviations imply that little disagreement was found between the users, suggesting that the incentive model elements work for all users in this target group.

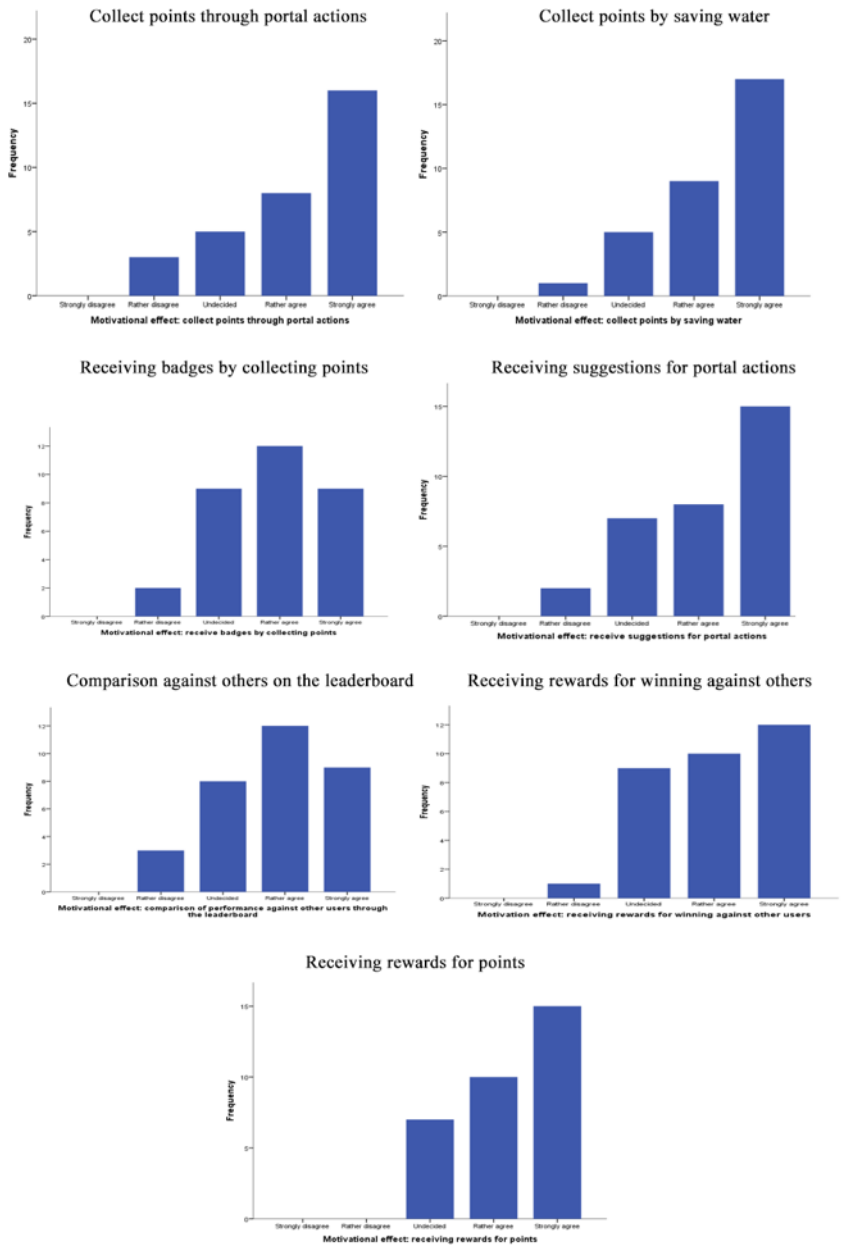

Figure 51: Motivational effect of gamification elements [89].

Motivational Effect of the Leaderboard (Spanish pilot)
With average scores of 3.8 and 3.5, respectively, users appear to feel motivated by their leaderboard position. However, it seems that the motivational effect of the Leaderboard is not as strong as the one provided by collecting point

and rewards. Those seems to have a stronger influence on their motivation, suggesting for this user base the need to collect is a stronger incentive than the need to compete (basic desires theory: subchapter 2.2.1).

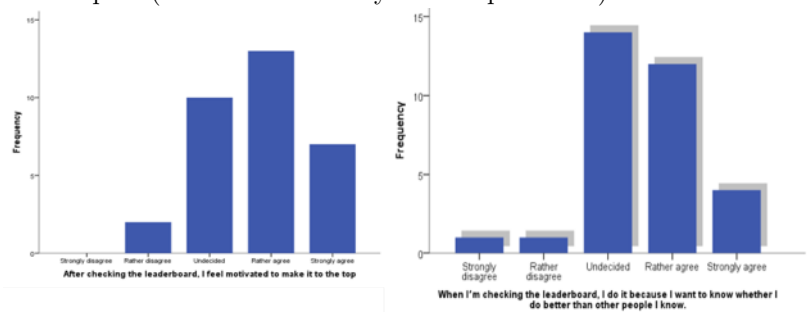

Figure 52: Motivational effect of competition through the leaderboard [89].

Consumption visualization and saving tips as incentives (Spanish pilot)

In addition to the gamification features that make up the core of the incentive model, the visualization of water consumption and provision of practical water saving tips also aim to serve as incentives to use the portal and raise awareness on water consumption. To assess their effectiveness, users were asked if they thought about water consumption more often than before, felt more motivated to save water and to use the portal. Results below (Figure 53).

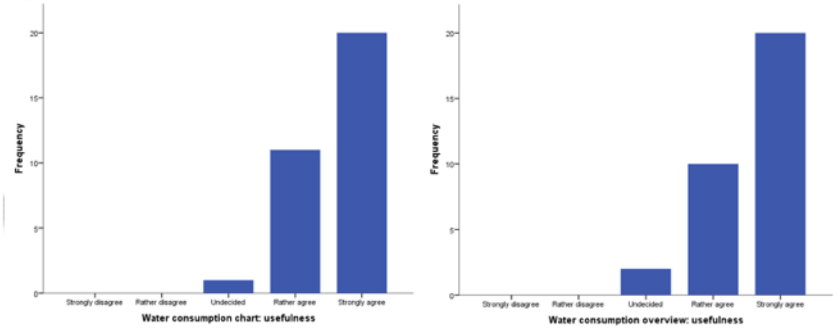

Figure 53: Perceived usefulness of water consumption chart [89].

Nearly all respondents stated that the water consumption chart and the water consumption overview made them think about water consumption more often and most of them even agreed strongly with this (Figure 54-1). Similarly, but with few more indecisive respondents, most also agreed that the chart and overview motivate them to save water (Figure 54-2). Differences between the chart and the overview were non-significant .

While the majority also found that the chart and overview motivated portal usage, a minority was undecided or, in the case of the consumption chart, disagreed (Figure 54-3). Overall, this is a very positive assessment that supports the rationale behind the approach of using the different ways of visualizing

consumption aimed to motivate water saving [89].

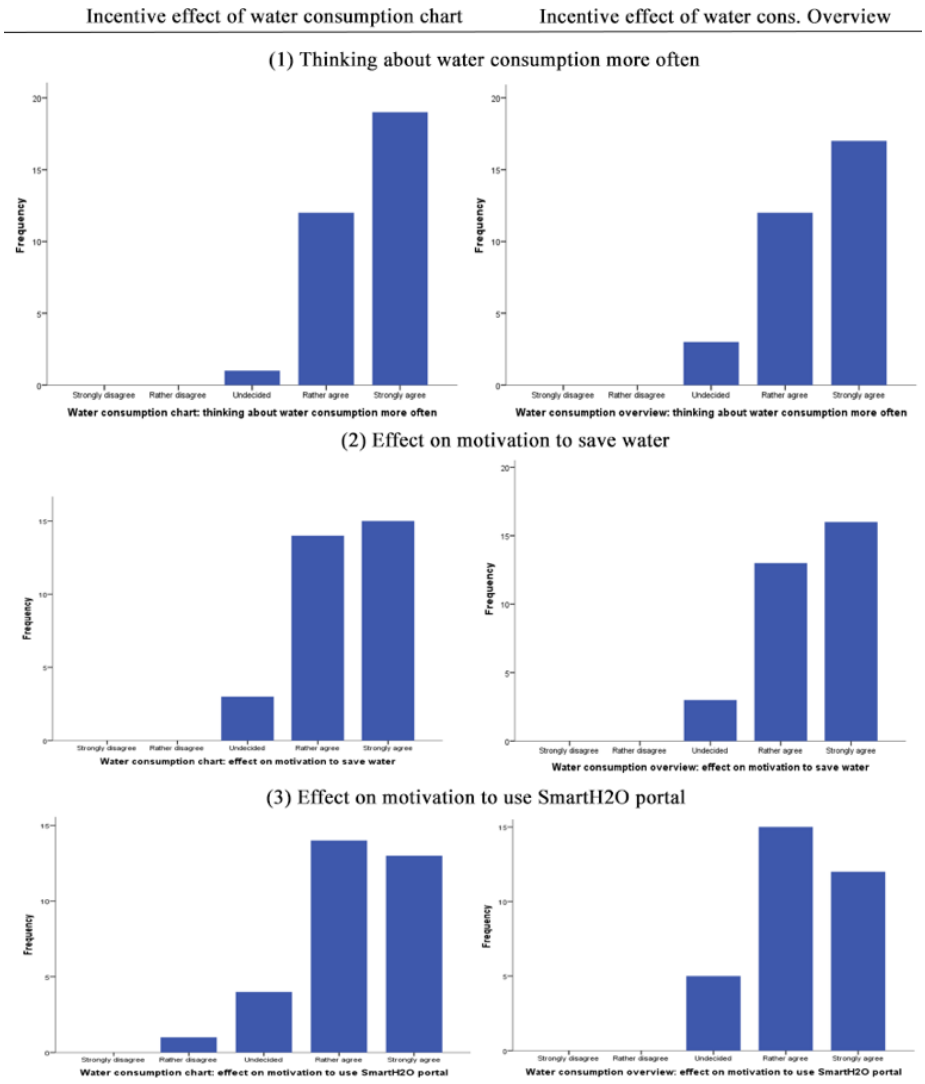

Figure 54: Incentive effect of water consumption chart [89].

The vast majority found the water consumption chart very effective towards understanding their own consumption (Figure 55-1). Responses towards individual features varied a bit more, but still draw an overall very positive point, with average values ranging from 3.6 to 4.1.
On the other hand, displaying a person own average was found very effective by nearly all users, and was also known to nearly all (Figure 55-2), roughly a

third of the users were more indecisive towards the effectiveness of displaying the neighborhood average (Figure 55-3) or viewing hourly consumption (Figure 55-4), and a (still relatively small) group stated they hadn't used these two options at all.
The relatively high averages suggest that the addition of interactivity that allows the comparison with own and neighborhood averages can support the users' understanding of their water consumption, which is expected to contribute to the user's awareness [89].

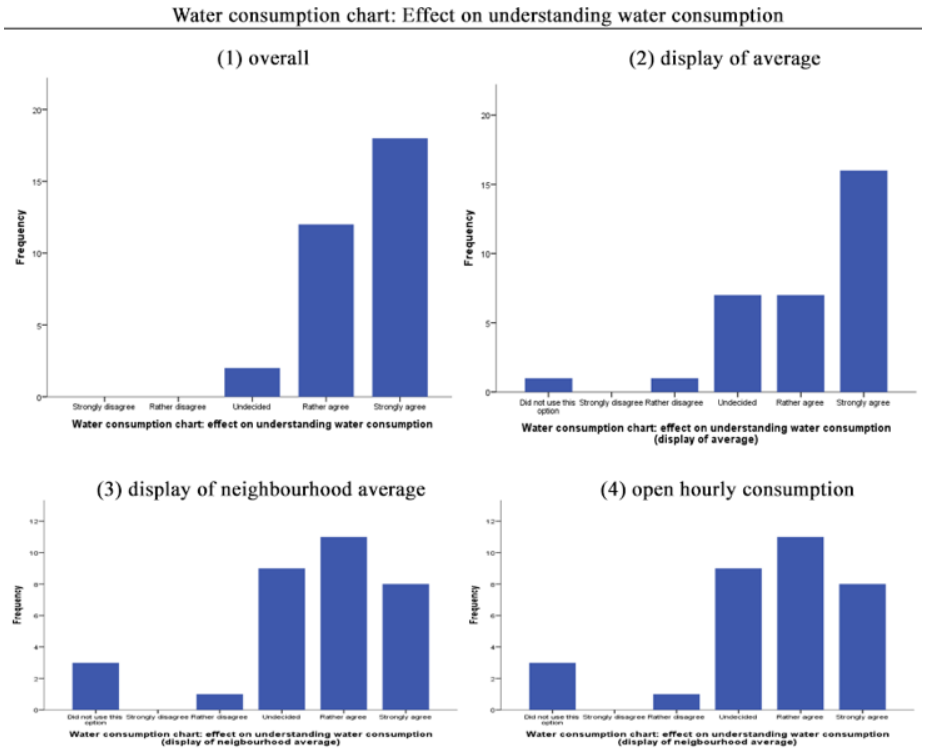

Figure 55: Water consumption chart: Effect on understanding water consumption [89].

The water consumption overview was also evaluated very positively regarding its effect on facilitating the understanding of water consumption (Figure 56-1). In detail, displaying the expected yearly consumption was assessed the most effective.
The interaction that was offered to users and the comparisons they can do, appear to stimulate engagement with water consumption, which was an underlying assumption of the SmartH2O incentive model (see Chapter 2) .

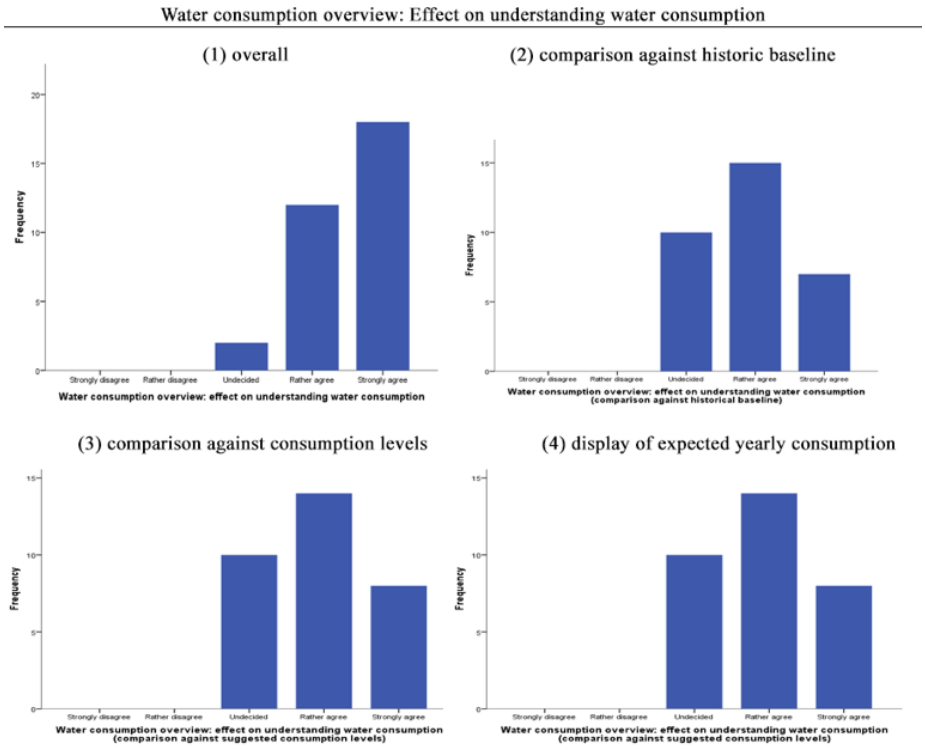

Figure 56: Water consumption overview: effect on understanding water consumption [89].

Water consumption alerts were found useful by a vast majority of people, as can be seen in the graph below (Figure 57). They could prove to be a strong incentive for people to use smart metering technology and accompanying visualizations and services. Consumption goals were also assessed as very useful by nearly all users [89].

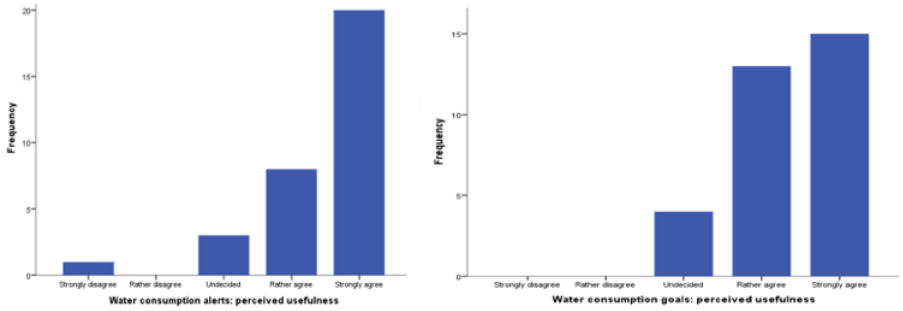

Figure 57: Perceived usefulness of consumption alerts (l) and goals (r) [89].

This is emphasized by the positive responses towards the incentive effect of the consumption goals. Overall, a vast majority strongly agreed that the consumption goals made them think more about water conservation than before (see Figure 58-1) and motivated them to save water (see Figure 58-2). They also stated that goals motivated them to use the SmartH2O portal (Figure 58-3), with a few indecisive responses. The individual elements were also assessed positively, and very similarly in terms of the level of agreement, although being able to compare consumption to goals (Figure 58-4) won in terms of positive responses on to the other two aspects of earning points for meeting consumption goals (see Figure 58-5) and being able to view expected savings when meeting a certain goal (Figure 58-6). The results assessed again the importance of goal setting mechanisms in the context of systems aiming at changes in awareness and behavior, by appealing to the user's sense of achievement (see subchapter 2.2.1) [89].

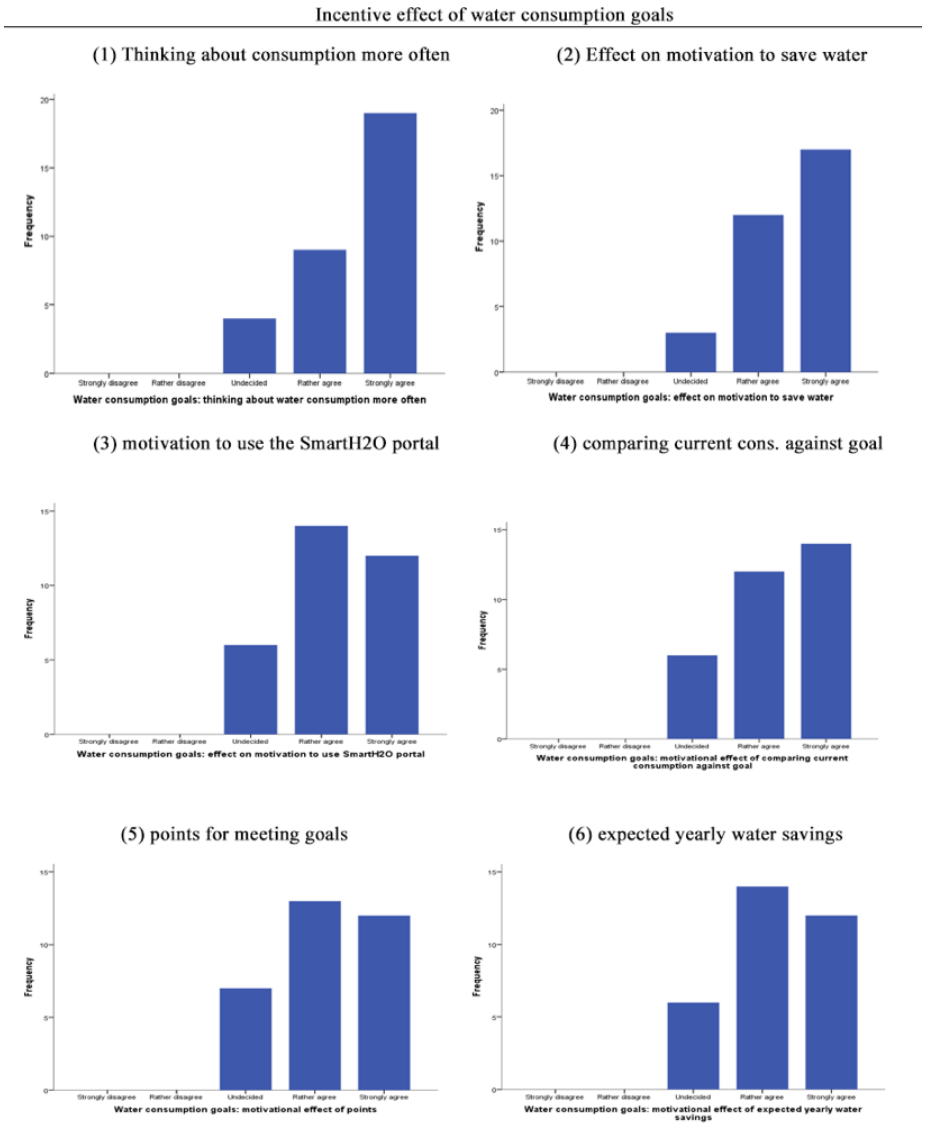

Figure 58: Incentive effect of water consumption goals [89].

Finally, water consumption tips were assessed in terms of their incentivizing effect. Respondents found them very useful (see Figure 59-1), and also stated they made them think about water consumption more often, with only very few who were indecisive or disagreed (see Figure 59-2). Respondents also strongly agreed that the tips motivate them to save water (see Figure 59-3), and to fairly large extent motivate them also to use the portal (see Figure 59-4). The stated motivation to put tips into practice (see Figure 59-5) is slightly higher than the

stated ability to follow through (see Figure 59-6). This can be the result of the users balancing three different goals in environmental behavior: hedonic goals, normative goals, and gain goals, with each of these goals gaining the upper hand in different situations (see 2.4.1) [36].
It can be concluded from the evaluation of the water consumption chart and overview that they are able to encourage a positive reflection on water consumption and are capable of increasing the user's motivation to save water, confirming the designed SmartH2O incentive model and its implementation.

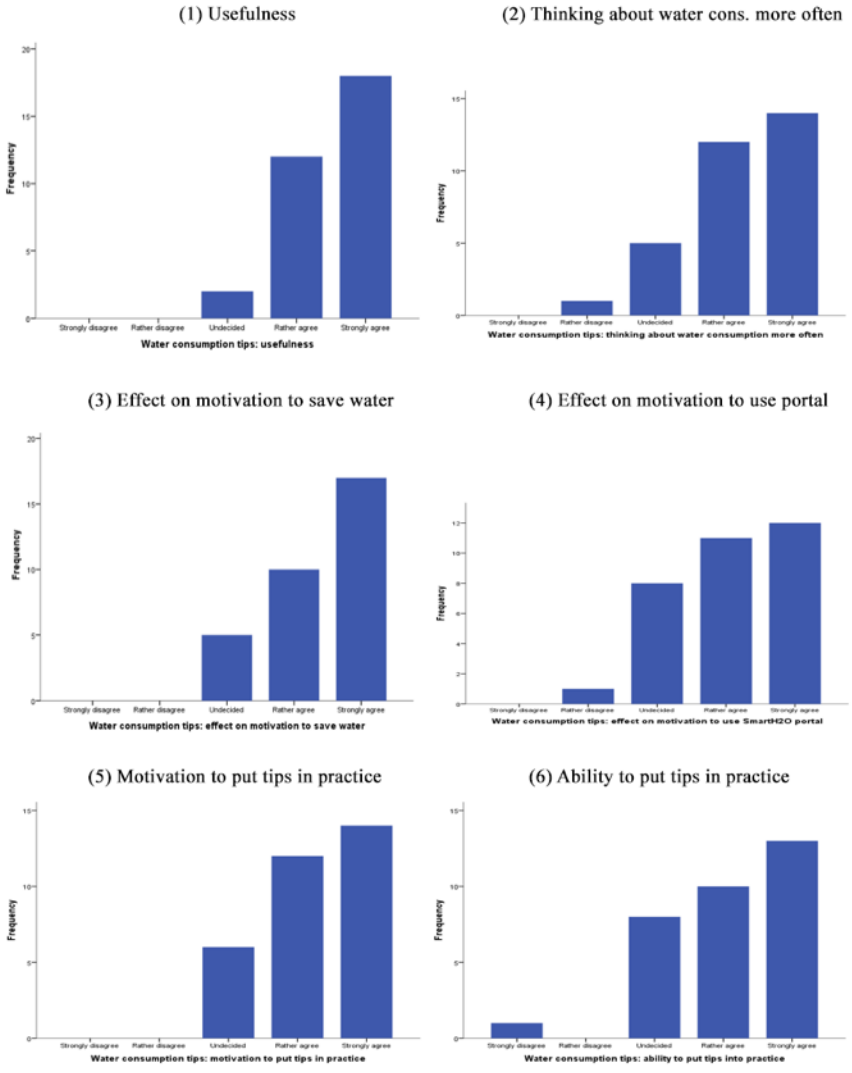

Figure 59: Water consumption tips as incentives [89].

Whereas the water consumption chart and overview have been intended to stim-

ulate thinking about one's water consumption amount, water consumption tips are offered to provide practical support with saving water [89].
The water saving tips are an important part of the SmartH2O incentive model that has proven to be effective, in terms of providing users with actionable tips, but also to raise awareness on water consumption.

6.3.1.2 Usage Data Analysis (Spanish pilot)

The first promotion campaign for the Spanish case study took place late May 2016. Since then a first use base has been established whose activity on the portal gives the first indications of the effectiveness of the incentive model described in Chapter 2. It assumes that interaction with gamified elements yields a motivation for portal usage that will subsequently motivate users to interact with water-related information (e.g. tips, water consumption visualizations, see subchapter 2.5). Below portal actions of the users are reviewed from this perspective.

Summary User Activity (Spanish pilot)

In Figure 60 the total number of actions on the portal is displayed, divided by the portal's functionalities.

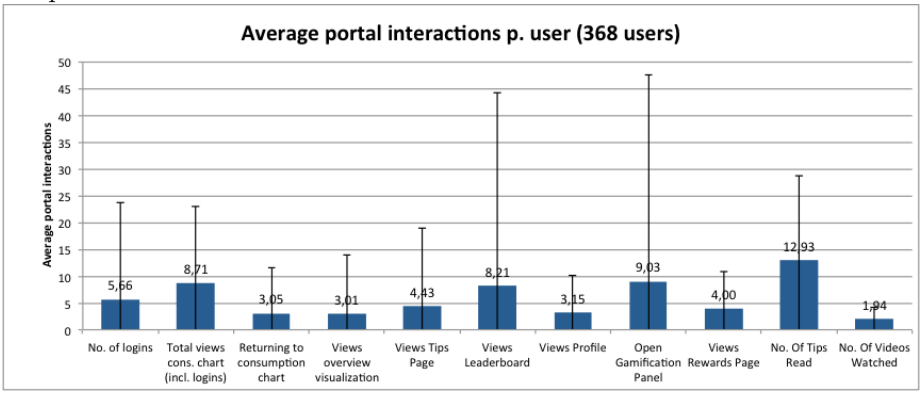

Figure 60: Average no. of portal actions per user, divided by functionality [89].

The results indicate that the water saving tips were most frequently inspected by the users, followed by a set of actions associated to the gamification functionalities (e.g. the gamification panel, leaderboard, tips for portal actions, rewards page), and the water consumption charts. Results indicate that users make use of all functionalities, in particular the gamification ones. However, inspection of the standard deviations revealed that there is a high variability among users
.
This is in line with the hypotheses behind the incentive model, in which in earlier phases of the behavioral change process we expect the motivational affordances from the gamification elements to be stronger, whereas in later phases of the process the water-related features will become more important once their intrinsic motivation for water conservation has been strengthened (see Chapter

2.4).

Interaction with gamification elements (Spanish pilot)
In the previous subsection (6.3.1.1) it was shown that users were very positive concerning the motivational effect of the gamification elements. In this subsection, there has been an investigation whether their opinions match the behavior users demonstrate on the portal. Two pillars of the gamified incentive model were addressed: the elements associated to virtual rewards (points, badges, leaderboards) and the physical rewards.
With respect to the first class, below there is a chart showing in detail the total number of points users have received (Figure 61) [89].

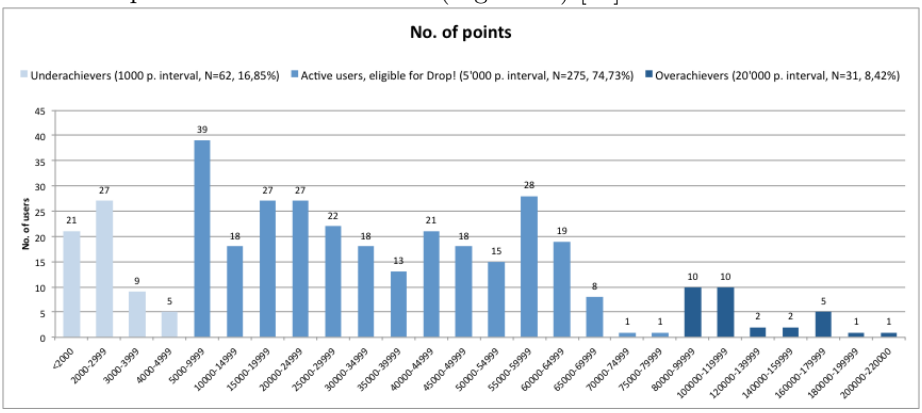

Figure 61: Number of points across users (Spanish case study) [89].

Subsequently, there has been an analysis of the badges users have received for their activity on the portal. In Figure 59 the badges distribution per user is displayed. The results demonstrate that the advanced profiler badge was assigned to 265 users (72.0%), suggesting that the onboarding process of motivating users to fill out their profile and the sign-up questionnaire for the validation has been successful. Between these users, 48 of them have even the super profiler badge, which is awarded when 4000 points have been collected in the profiling area.
A still very substantial 50.3% (185 users) has gained the Smart saver badge, suggesting that they have been reviewing tips and videos to save water. Slightly less at 43.3% (160 users) have been involved in saving water, by inspecting water consumption statistics and setting goals.

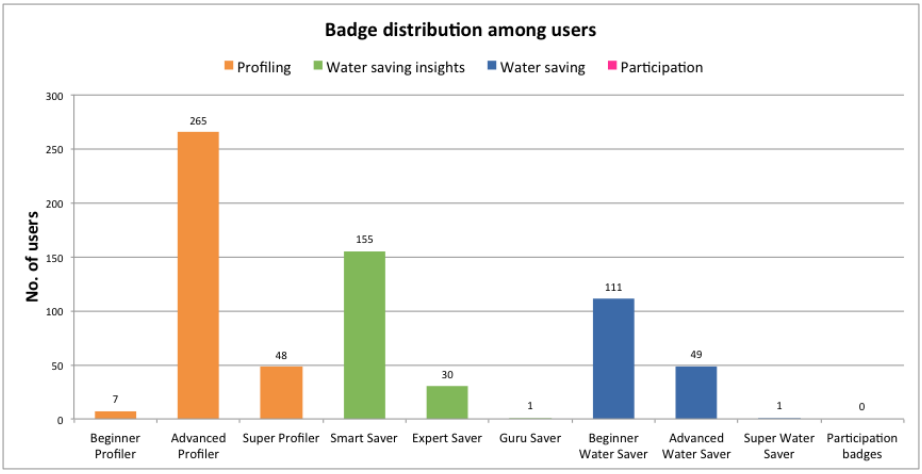

Figure 62: Badge distribution among users (Spanish case study) [89].

Physical rewards were awarded to users who have received 5000 points or more. Additionally, tickets to the oceanographic museum were awarded to those users who won the weekly competition. The statistics of users eligible for rewards, rewards claimed, and rewards picked up are displayed in Table 1.

Table 28: Rewards for users in Spanish case study [89]

	Eligible	**Picked up**	**Claimed**	**Eligible but not claimed**
Drop! (5000p)	236	42	45	149
Tickets (weekly competition winner)	18	13	3	2

The table demonstrates that 236 users were eligible for *Drop!*, meaning that these users have performed a first basic set of platform actions in different thematic areas. The 17.8% of the users eligible for the *Drop*! Game has picked up the game, whereas 19.0% has claimed the game, but has not picked it up. Thus, 42 users were that much interested in saving water and discussing water consumption in their household that they were willing to physically go to the pick-up point to collect the game. Given this required effort, the high share of users not claiming the game is not surprising [89].
For the weekly competition winners, the balance is different. A free ticket to a renowned museum seems to be a stronger incentive to take the effort of going to the pick-up point. 72.2% of the winners has picked up their reward, whereas only 2 users (11.1%) have not claimed their rewards, and only three users (16.7%) have claimed the ticket, but have not picked it up [89].

Interaction with water consumption visualizations and goals (Spanish pilot)

While the behavioral change model suggests that interactions with water consumption information can typically not be expected in the very first phases of the behavioral change process, the log data reveal that a significant number of interactions have already taking place, both with the water consumption chart and with water consumption overview .

The average number of interactions with the different water consumption charts and visualizations is shown in Figure 63.

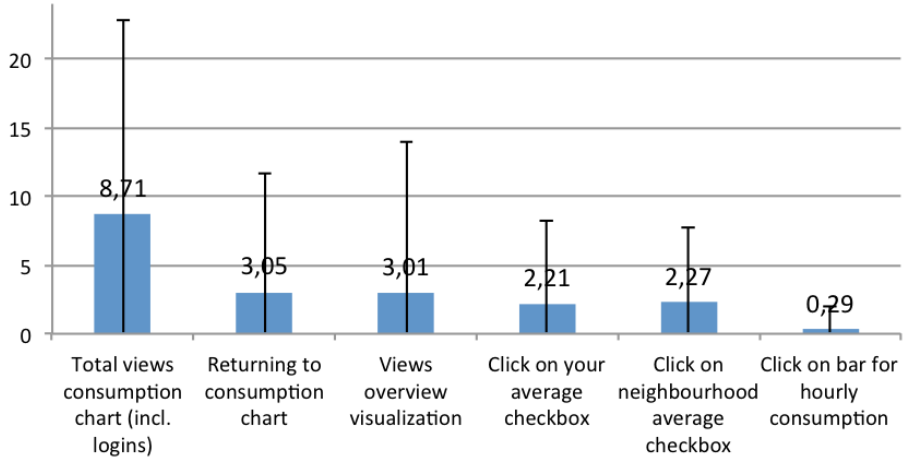

Figure 63: Average number of interactions with water consumption visualizations [89].

Those results show that the consumption overview and the consumption chart were used with approximately the same frequency. The total number of views for the chart is substantially higher because the chart is the first page that is loaded after users log in. Therefore, we consider the users returning to the chart to be a more reliable number. This number of interactions with the charts are encouraging, as has been said, given the current stage of the behavioral change process.

In terms of the chart's options, the comparison options for the average consumption and the average consumption of similar households in the neighborhood are used with a similar frequency. The hourly consumption option is used substantially less frequently.

The feedback of the users in the questionnaire revealed that they think the neighborhood comparison option to be the less useful for understanding their water consumption, but the log data reveal that the options are used just as frequently. When more usage data becomes available, it can be observed the usage of this option declines after this initial usage, or that there is a lasting discrepancy between the users' perceptions and their behavior [89].

Finally, there has been inspected the achieved weekly and monthly savings and the goals users have set for themselves. Results are displayed below (Figure 61).

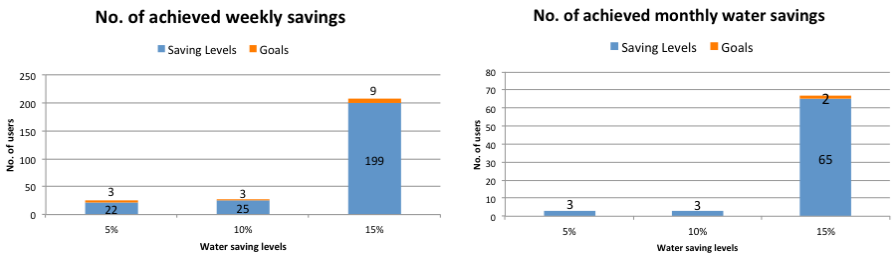

Figure 64: Water saving goals (Spanish case study) [89].

Whereas in the incentive model users were expected to set goals in later phases (e.g. in the action phase; see subchapter 2.4.4), over the evaluation timeframe, 15 users have already set a weekly goal, and two users an ambitious 15% water saving goal. These numbers indicate that already a number of lead users are incentivized by the goal setting functionality to reduce their water consumption and to meet their self-set targets. In addition, a significant number of users have already received points for reducing their water consumption [89].

Lead user analysis (Spanish pilot)

A more detailed inspection of a limited number of active lead users can reveal behavioral patterns that distinguish different types of users, even if the first analysis done in the previous sections has shown the effectiveness of the SmartH2O incentive model. Five users were selected with more than 80.000 points, which is approximately the mean number of points plus one standard deviation (see Figure 65).

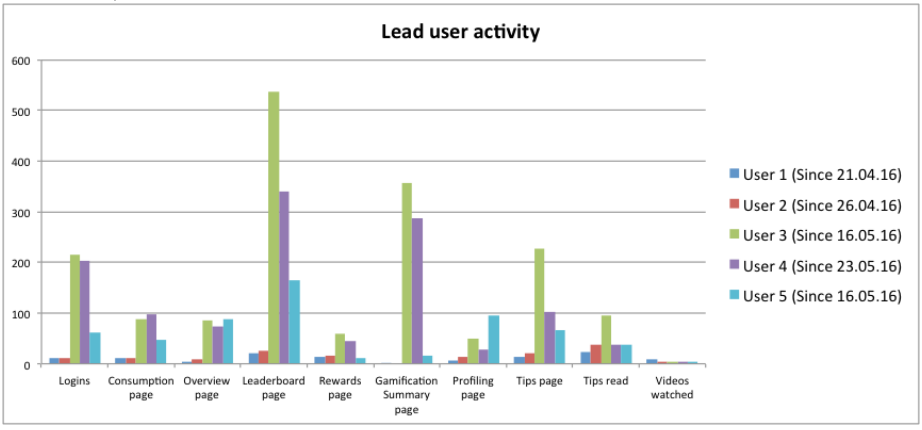

Figure 65: Lead user activity divided by functionalities (Spanish case study) [89].

Inspection of the graph demonstrates that for all users in this analysis most activity is concerned with the gamification functionalities. Then, both the water saving tips and the consumption visualizations attract the attention of these lead users. This pattern is consistent with the pattern that was found for the user base at large, even though the level of activity for these lead users is substantially

higher.
User #3 is overall the most active user, but his/her engagement with the gamified features stands out from the rest. This user often visits the leaderboard page, and the gamification summary in the sidebar. S/he seems very interested in the weekly competition, since the leaderboard received more than 500 page views of this particular user. In addition to the gamification features, the tips pages are often read. User #4 is similar, exception made for the number of visits of the leaderboard and the tips page, less than user #3.
User #1 and #2 display overall a lower level of activity than user #3 and #4. Their activities are more evenly spread over the different portal functionalities. Interestingly, they quite frequently read water conservation tips.
User #5 is moderately active on the portal. Two particular actions on the portal stand out. First, the user frequently inspects the consumption overview page, second, the profiling page is also frequently visited. This could be the result of the onboarding process that incentivizes users to complete their user profile, yielding more page views during this initial phase of the process. Further analyses should reveal whether profiling activities become less prominent over time.

6.3.2 Swiss use case

This section presents the first validation results from the Swiss case study, containing the users' feedback on the basic portal, as well as precise data on their awareness with respect to water consumption, both coming from the studied behavior during the timespan and the questionnaire results. Additionally, baseline and first water consumption measurements after the launch of the SmartH2O portal are reported. Even though the time frame does not yet cover a full year – to rule out seasonal variations – first results are promising.

6.3.1.1 Questionnaire results

This subchapter reports the questionnaire results, in terms of technology acceptance and the effectiveness of the incentive model, as perceived by the users in the Swiss case study. In sum, out of the 23 users of the gamified portal, 10 participants filled out the questionnaire. This 43% response rate is very high when compared against response rates common for evaluations of online applications.

Technology acceptance (Swiss pilot)
From the UTAUT framework [28], effort expectancy, performance expectancy, and attitude towards technology were measured. In Figure 66 'effort expectancy' results are displayed, as a measure of the perceived ease of use.
The very positive results on the ease of use of the portal indicate that the portal has been capable of combining gamified incentives with water-related information in an easily understandable way.

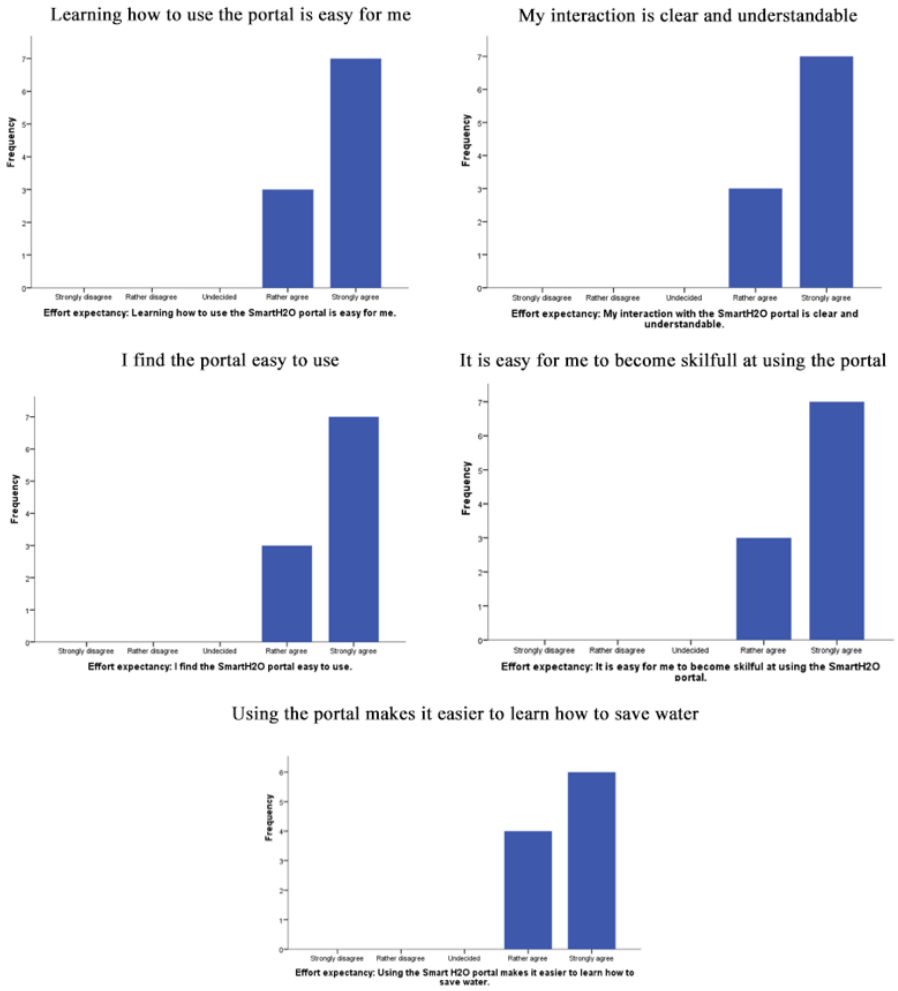

Figure 66: Effort expectancy item results [89].

Performance expectancy was measured with two items, displayed in Figure 64, indicating that the portal has the potential to influence people's daily lives and things that are important to them in a positive manner.

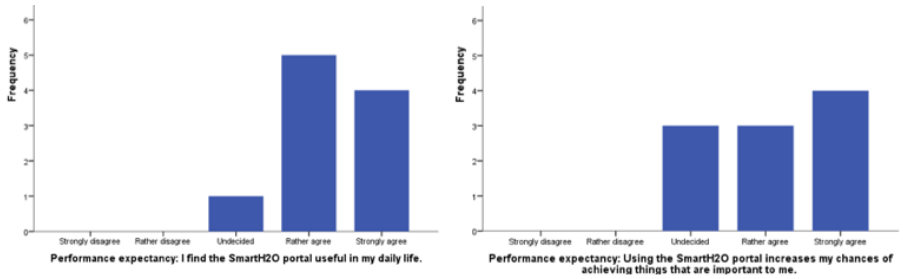

Figure 67: Performance expectancy item results [89].

Attitude towards technology (Swiss pilot)

Similar to the performance expectancy and effort expectancy results, users had a positive attitude towards the SmartH2O portal (Figure 68). Users were a bit more indecisive towards finding the portal fun to use. All users agreed they liked using it, that using it was a good idea and that it made water conservation more interesting. A majority even indicated that they strongly agreed to those statements.

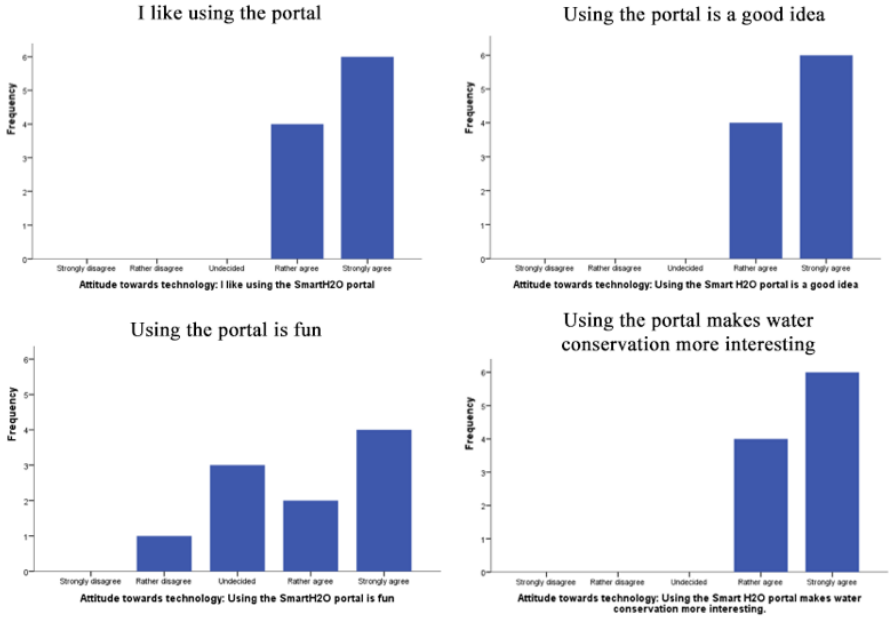

Figure 68: Attitude towards technology item results [89].

It can be concluded from the UTAUT results, that the users in the Swiss pilot considered the portal easy to use, useful, and that they also liked to use the portal [89].

Hedonic and pragmatic quality (Swiss pilot)
Hedonic and pragmatic quality were measured using the *AttrakDiff2* questionnaire, of which hedonic quality (stimulation) and pragmatic quality were measured. The scores of the seven individual items were averaged, yielding an average pragmatic quality score of 6.0 and a hedonic quality (stimulation) average of 5.9. The distributions of the scale averages are displayed in Figure 69 [89].

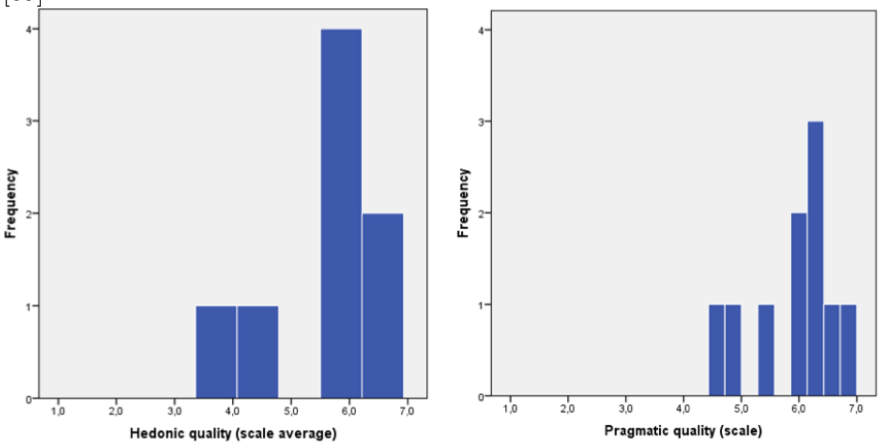

Figure 69: Average hedonic quality (left) and pragmatic quality (right) scores [89].

The closely matched and high average scores indicate that the SmartH2O portal is capable of providing users with a stimulating user experience that is well-balanced against the pragmatic goals of the users (e.g. learning about their water consumption). Whereas the portal aims to convey the meaning of the water consumption data to users as an inducement to start saving water, the users find this information useful. On the other hand, the portal encourages users through gamification and encourages users to think about water consumption. This is reflected in the results from the hedonic quality questions. In summary, the hedonistic and pragmatic quality of the portal are well balanced [89].

Gamification elements as incentives (Swiss pilot)
The primary goal of this round of feedback was to evaluate user-based performance indicators that focus on the motivational affordances of the portal's gamified features. Figure 70 displays the results.

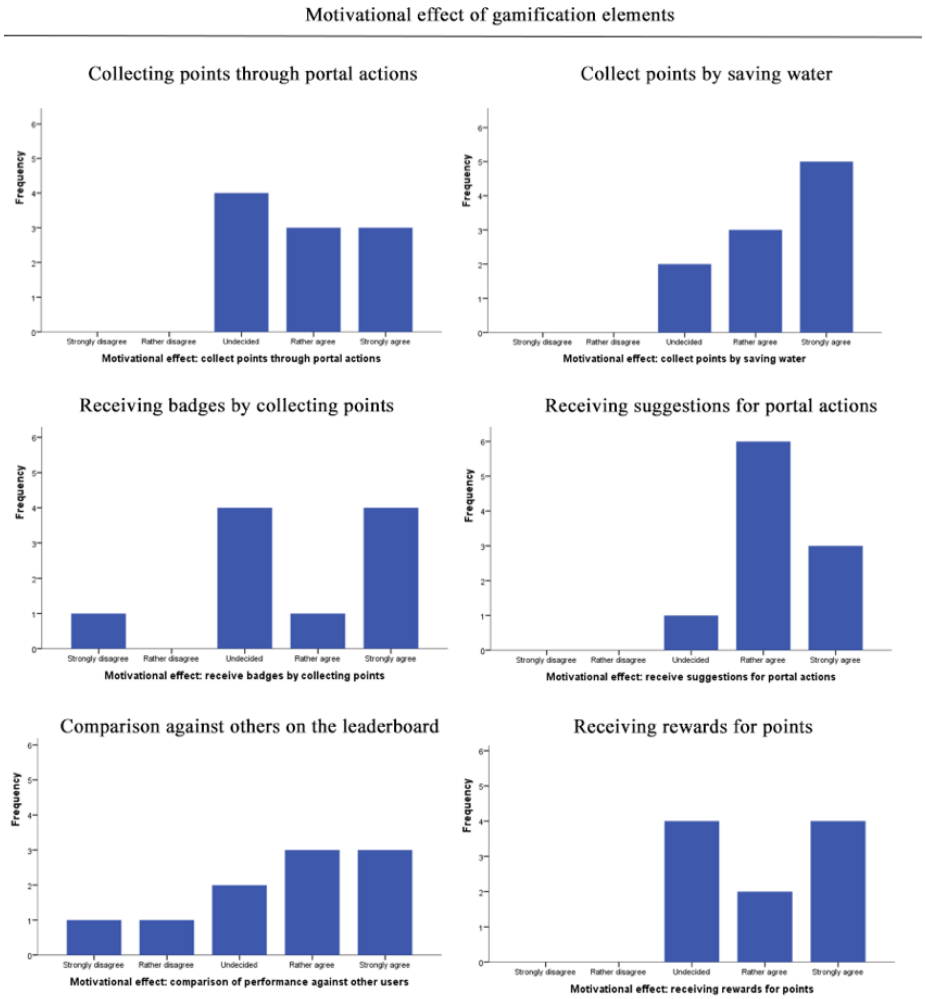

Figure 70: Motivational effect of gamification elements [89].

While collecting points through portal actions was perceived as a motivator by most users, collecting points by saving water was strongly confirmed to be a motivator for portal usage. This indicates that the approach the SmartH2O portal is taking by rewarding significantly more points to water saving could indeed be going into the right direction towards facilitating usage and raising awareness.

Opinions about badges are a bit more different between users, yielding either strong agreement about their motivational affordance or indecisiveness. Actionable suggestions on what users can do on the portal were also found motivating aspects towards portal usage. 6 out of 10 users found the comparison against others on a leaderboard motivating.

Receiving rewards in exchange for points was assessed to be more motivating (6

out of 10 users), which could possibly indicate that the market place approach has been an appropriate choice for this particular case study. Overall, responses are rather positive towards the applied gamification elements, but further investigation should be done towards more indecisive users [89].

Motivational Effect of the Leaderboard (Swiss pilot)
Responses to two additional questions about the leaderboard (see Figure 71) indicate that the leaderboard may foster competitiveness among users, or that users that are using the portal are by selection more competitive. As has been said in the previous point, most of the users have found the comparison against others on a leaderboard motivating [89].

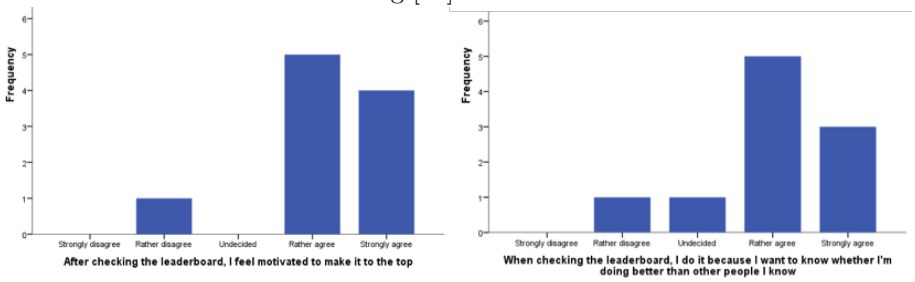

Figure 71: Motivational effect of competition through the leaderboard [89].

Consumption visualization and saving tips as incentives (Swiss pilot)
Since Swiss users started to use the portal with a different consumption visualization UI, some data about that was already been collected. It was assessed easy to very easy by over half the respondents while the others remained neutral, nearly all respondents agreed that they could understand from both the chart and the overview visualization how much water their household consumes over time and at least half the participants found the consumption chart and overview visualization useful and only very few didn't see their use yet [85]. According to this data, the focus of this evaluation has been the new water consumption overview in addition to the gamification incentives. Users in the Swiss case study strongly agreed that the water consumption overview visualization was useful (Figure 69-1), and also agreed that it made them think about water conservation more often than before (Figure 69-2). The level of agreement towards the latter was higher than responses to the same question about the chart and first overview version in the first evaluation round, indicating tentatively that the current UI could be even more effective to convey meaning and purpose of water saving [89].
Users also stated that the visualization motivates them to save water (Figure 72-3), and to an even slightly larger extent agreeing that it motivates portal usage (Figure 72-4), showing that a more playful visualization does also have the potential to greatly influence both portal usage but also users' drive to save water [89].

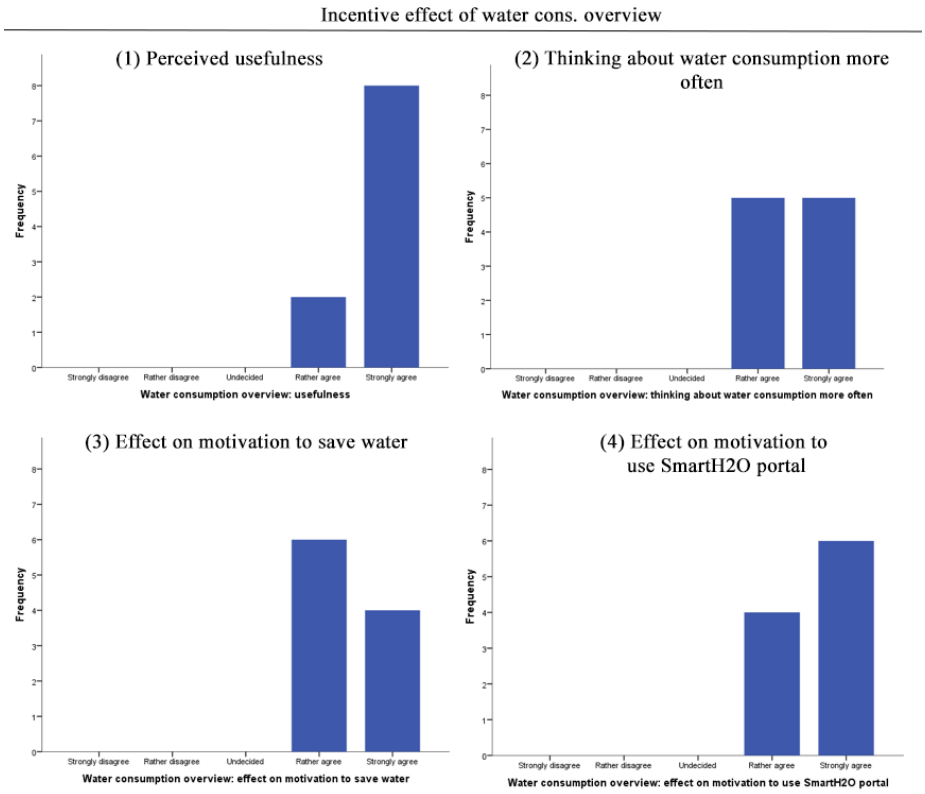

Figure 72: Incentive effect of water consumption overview [89].

Users strongly agreed that the overview visualization helped them in understanding their water consumption, with 8 out of 10 even agreeing strongly (Figure 73-1). All three main elements of the consumption overview seem to attribute to that almost equally (Figure 73-2,3,4).

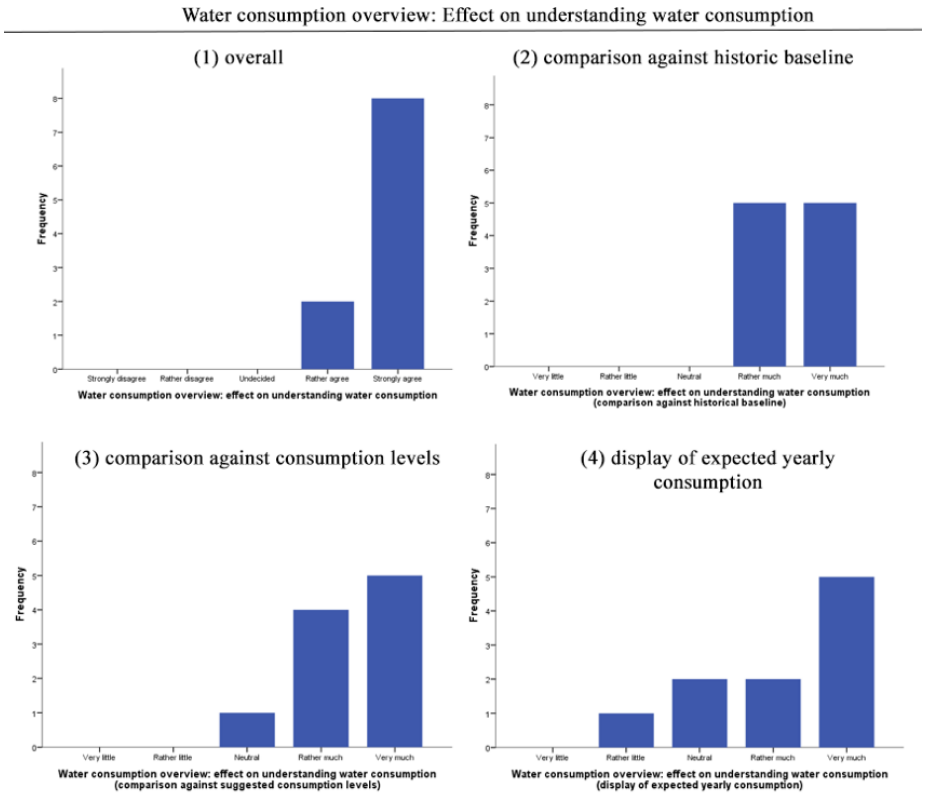

Figure 73: Water consumption overview: effect on understanding water consumption [89].

This result is very positive for the SmartH2O project, because it means that the incentive model strongly assumes that understanding of one's water consumption could lead to favorable attitudes and ultimately behavior [89].
Alerts were found useful by 7 of 9 users, whereas the other 2 disagreed (Figure 71-left). Water consumption goals were found useful by all respondents (Figure 71-right), which was also confirmed in the positive responses to the follow-up questions [89].

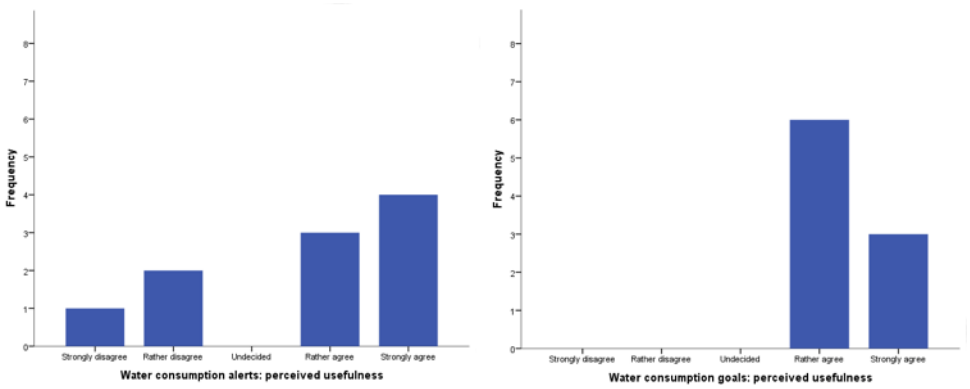

Figure 71 - Perceived usefulness of water consumption alerts (l) and goals (r) . Users agreed that the water consumption goals made them think about water consumption more often (Figure 75-1), and that they motivated them to save water (Figure 75-2). To the same extent, they also claimed it motivated them to use the portal (Figure 75-3). They also found it motivating to be able to compare their consumption against goals (Figure 75-4), and 6 out of 9 users agreed that receiving points for meeting goals was motivating (Figure 75-5). The aspect of seeing yearly water savings in relation to goals was also found motivating (Figure 75-6). In summary, these are great tentative results for users' attitude towards goals, indicating the possible importance of goals as part of incentive models [89].

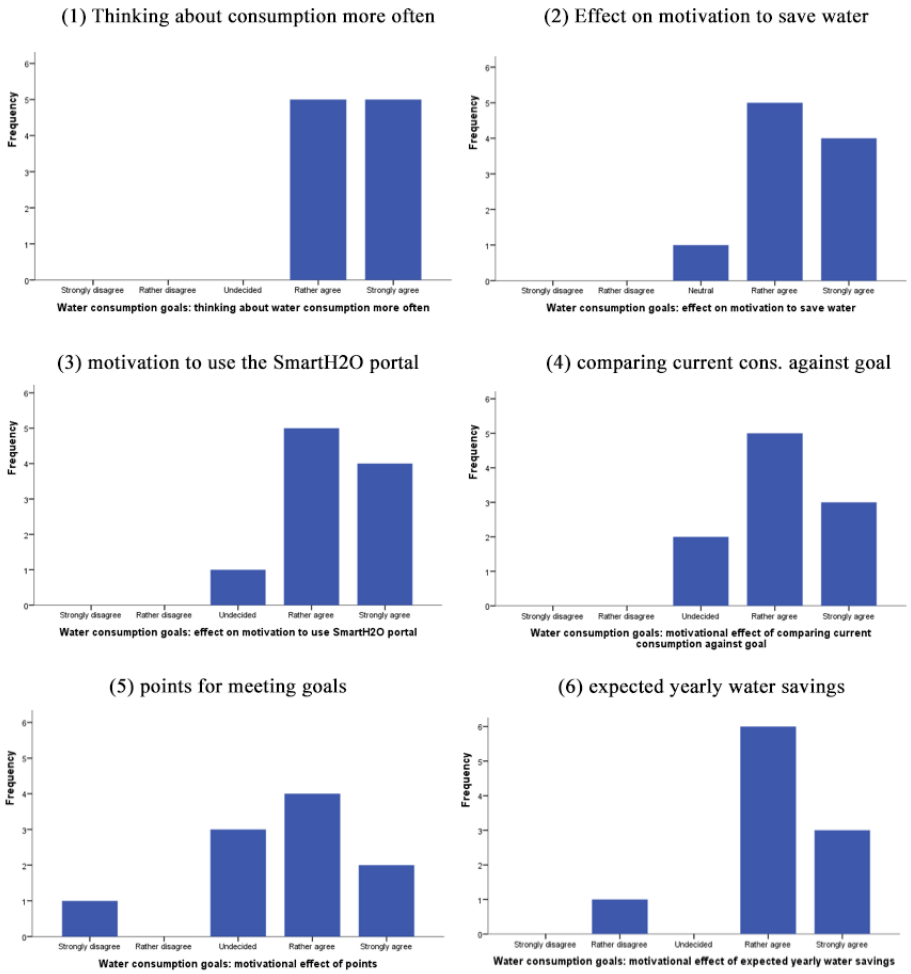

Figure 74: Incentive effect of water consumption goals [89].

6.3.1.2 Usage Data Analysis (Swiss pilot)

From November 2015, user activity in the Swiss case study has been logged (joint release with basic portal V2 on October 26, 2015).

As has been discussed at the beginning of this subchapter, the Swiss case study should be considered a test bed for the bigger case study, due to the limited number of users.

While the set of data on the success criteria for the gamified portal is not yet complete, some positive trends with respect to the defined feature-based success criteria can already be observed at this early evaluation stage. In this subsection, some of these early results have been reported, based on the analysis

of the gamified portal activity in general [85].

Summary of user activity (Swiss pilot)
First, an inspection on the registration date for the gamified portal has been done, as shown in Figure 76.

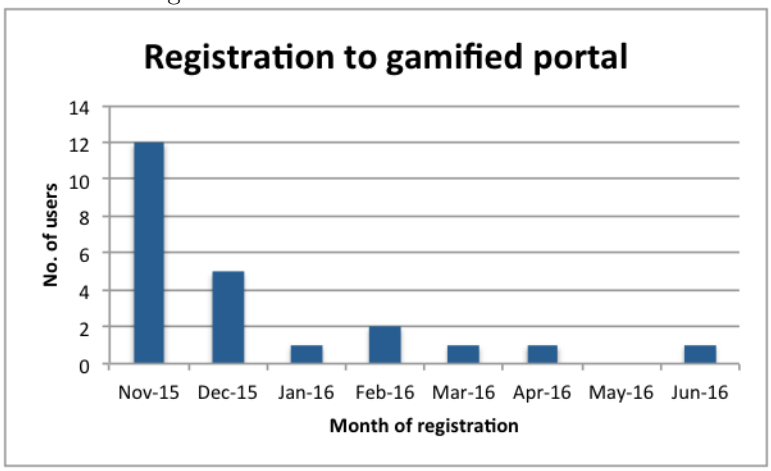

Figure 75: Registration date for the gamified portal (Swiss case study) [89].

After the launch of the gamified portal in early December a clear difference between basic portal usage and gamified portal usage could be observed: gamified portal users log in more frequently (Figure 77), showing that the gamified incentive model does stimulate portal usage to the extent that it becomes visible even in such a small-scale case study.

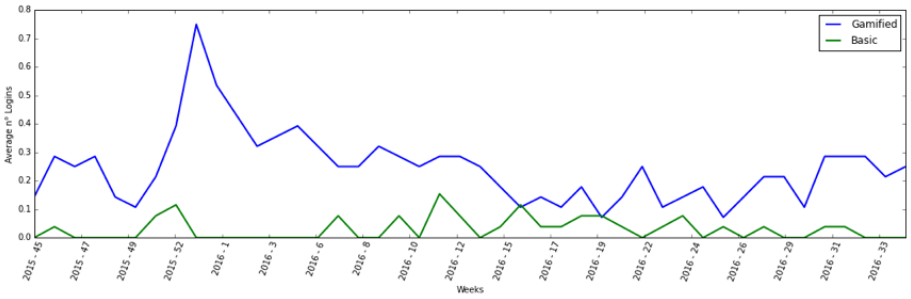

Figure 76: Average no. of logins per week of gamified vs. basic portal users [89].

As can be seen from the chart, the login pattern follows approximately the same shape, but is at a higher level for the advanced portal than for the basic portal [89].
Next we inspected the average number of portal interactions per user, divided by the different functionalities in the portal. Results are shown in Figure 78.

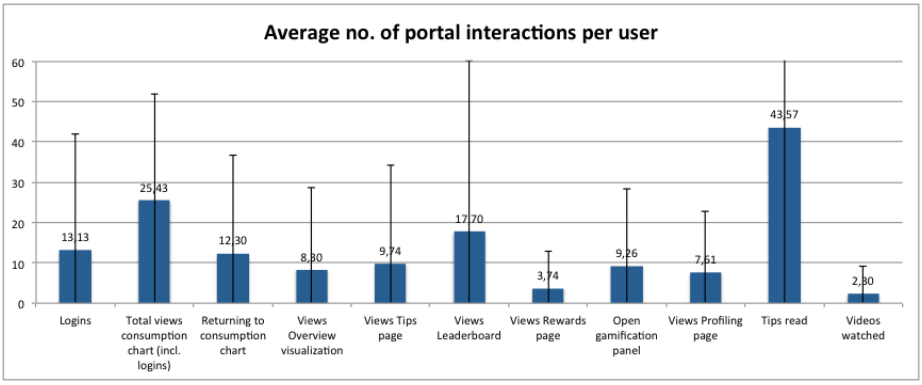

Figure 77: Average number of portal interactions per user (Swiss case study) [89].

The chart reveals that the water consumption tips have received most attention from the users, judged from the high total number of views. However, standard deviation is very high, indicating that there is a large difference between the users. Apart from the water saving tips, the leaderboard and the water consumption charts are also frequently inspected, suggesting that the users are sensitive to competition with other users.
The rewards page was viewed less frequently. This result is inconsistent with the strong motivational pull from the physical rewards the users have reported in the questionnaire (see subsection 6.3.1.1). The Swiss case study is then too small to draw finite conclusions about the effectiveness of the rewards part of the incentive model.

Interaction with gamification elements (Swiss pilot)
As a first assessment of the users' interaction with the gamified elements, the distribution of the number of points were analyzed. In contrast to the Spanish case, in Switzerland points are deducted once you have claimed a reward. Consequently, the total number of collected points is higher than the current total number of points displayed on the portal. Figure 76 displays the current score and the points spent on rewards.

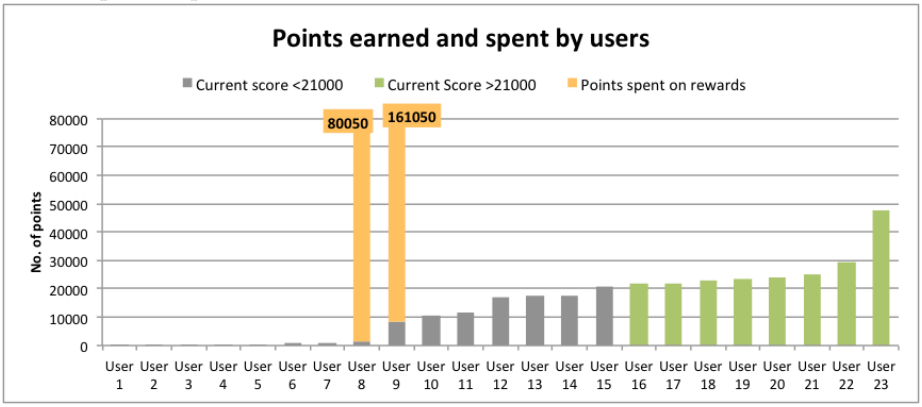

Figure 78: Distribution of points and available rewards (Swiss case study) [89].

Results reveal a typical pattern of a majority that is moderately active in terms of points collected, while two of the lead users collect more than 80.000 points each. There is also a relatively large group of users (User #6-User #23) who have collected a significant number of points, but have not claimed any rewards. Next, the assignment of badges will be inspected, divided by the thematic areas. The results are depicted in Figure 80.

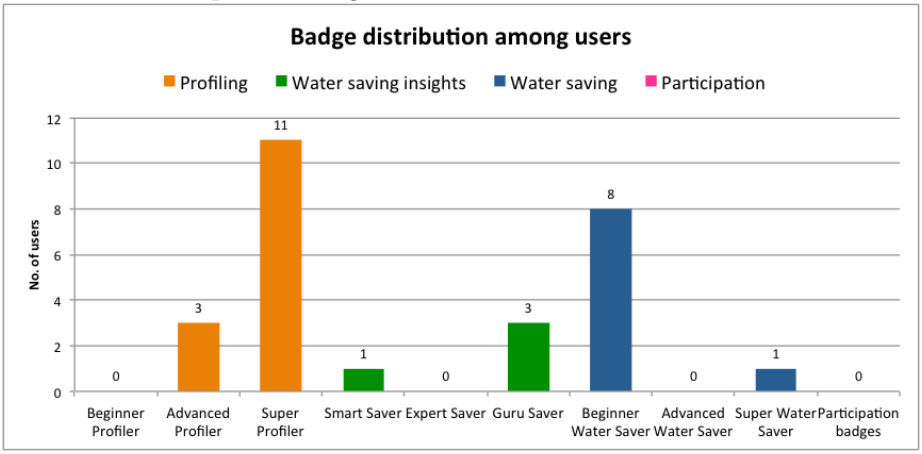

Figure 79: Distribution of badges among users, divided by type (Swiss case study) [89].

As can be seen from Figure 80 most assigned badges are in the profiling thematic area (in total 14), followed by the water saver area (in total 9), and the water saving insights (4). These results suggest that users are actively using the functionalities associated to all thematic areas, with higher numbers for the profiling activities. This is not surprising, since as part of the onboarding process, users are incentivized to complete their user profile and fill out the sign-up questionnaire.

Interaction with water consumption visualizations and goals (Swiss pilot)

In addition to the gamification actions, users' interactions with the consumption visualization were analyzed. The average number of interactions with the different water consumption charts and visualizations is shown in Figure 81.

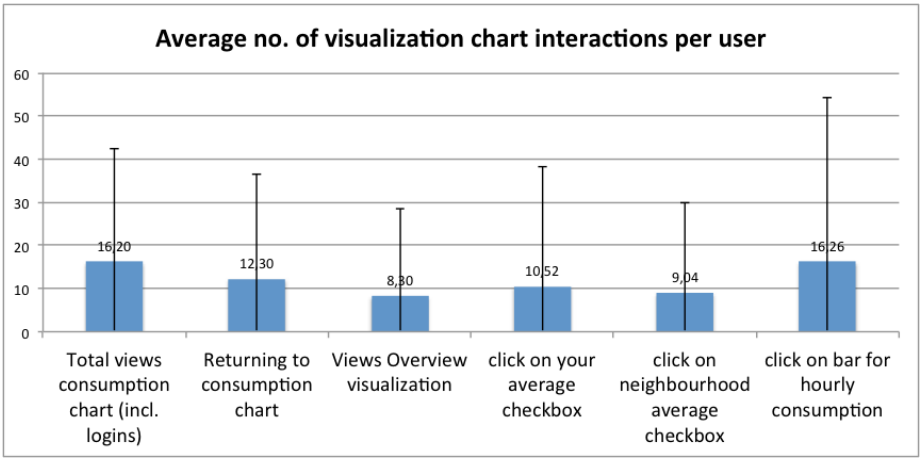

Figure 80: Average no. of visualization chart interactions per user (Swiss case study) [89].

The average no. of visualization chart interactions per user is quite high, while the high standard deviations (Figure 81) also reflect larger variations among users. The fact that returns to the consumption chart are twice as high as overview visualization views may be due to the fact that users in the Swiss case study are generally a bit more conservative and data-oriented when it comes to viewing their consumption. This heightened interest in detailed consumption information is also reflected in the high number of clicks on the hourly consumption chart.
Clicking on the neighborhood average is also a popular interactive feature, and the relatively small difference to the number of neighborhood average clicks also shows that comparison of consumption against one's own average and against the neighborhood average is nearly equally important to users.
For what concerns the Goals settings, as can be seen in Figure 82, half the users have reached weekly water saving levels, with an average of 2.48 weekly water saving levels per user. One user stands out with a significantly large number of weekly water savings of close to 30.

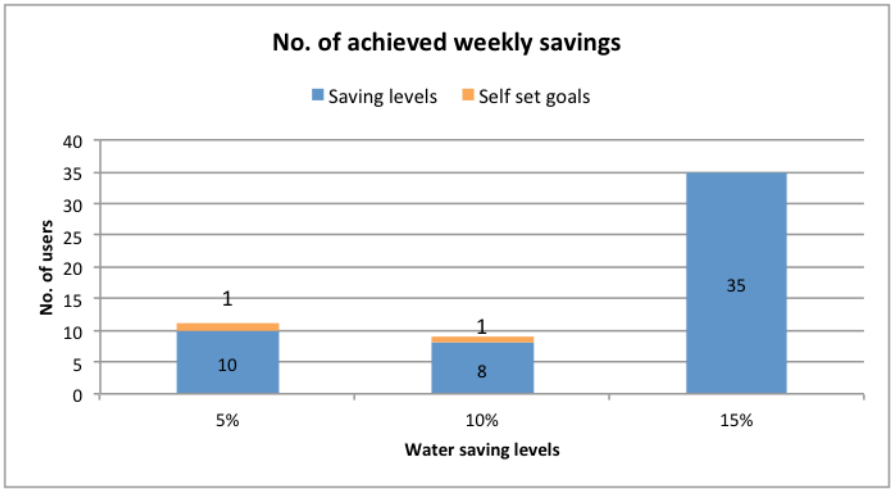

Figure 81: No. of achieved weekly water savings (Swiss case study) [89].

The logs show that two users (about 10%) have used the goal setting mechanisms. Other users have not yet displayed interaction with the goal setting mechanisms. One possible explanation is that users are not so aware of this feature, as it is not a default view. Since the weekly status that will be sent out via e-mail following the upcoming release will put the overview visualization more into focus, this is likely to change. In addition, the SmartH2O mobile app that will also be released in the Swiss case study features the overview visualization more prominently, too, putting it yet more into focus.

6.4 Questionnaires result on the mobile app

As has been said, results reported below are just a preliminary investigation about the impact that the mobile application could have on the users of the SmartH2O platform. Only a few number of people, the alpha testers, have filled the questionnaire about the evaluation of the SmartH2O app, making a real evaluation of the effectiveness of such an app impossible at the time of this thesis.

Technology acceptance (mobile version)
From the UTAUT framework [28], effort expectancy, performance expectancy, and attitude towards technology were measured. In Figure 82 "effort expectancy" results are displayed, as a measure of the perceived ease of use.

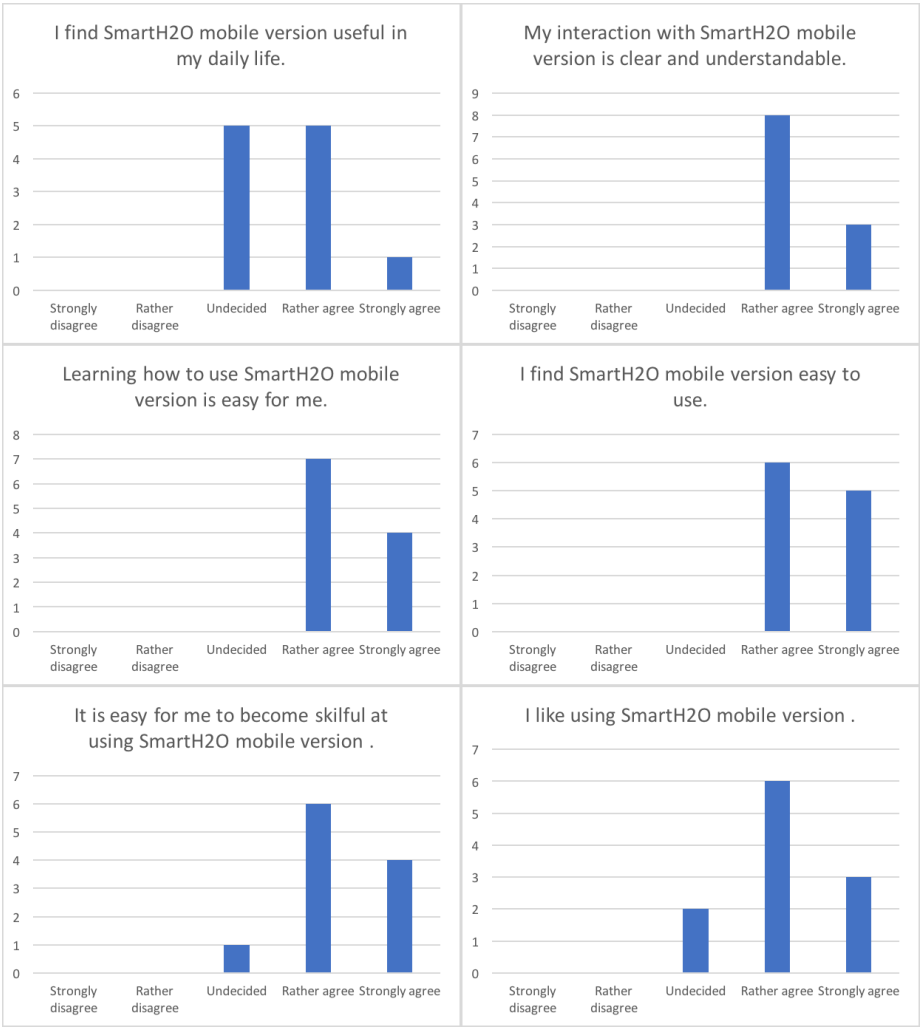

Figure 82: UTAUT: Effort expectancy item results (mobile)

As can be seen, alpha testers had a positive attitude towards the SmartH2O mobile app, in fact they considered the app easy and understandable. This result suggest that the motivational affordances included in the mobile application have been effective to raise interest in water conservation, the extent that this can be judged from self-reported measures. The majority thinks the application is useful, just a few users are undecided.
The UTAUT results on effort expectancy, performance expectancy, and attitude towards technology [28] suggest that the SmartH2O mobile application is considered ease to use and useful.

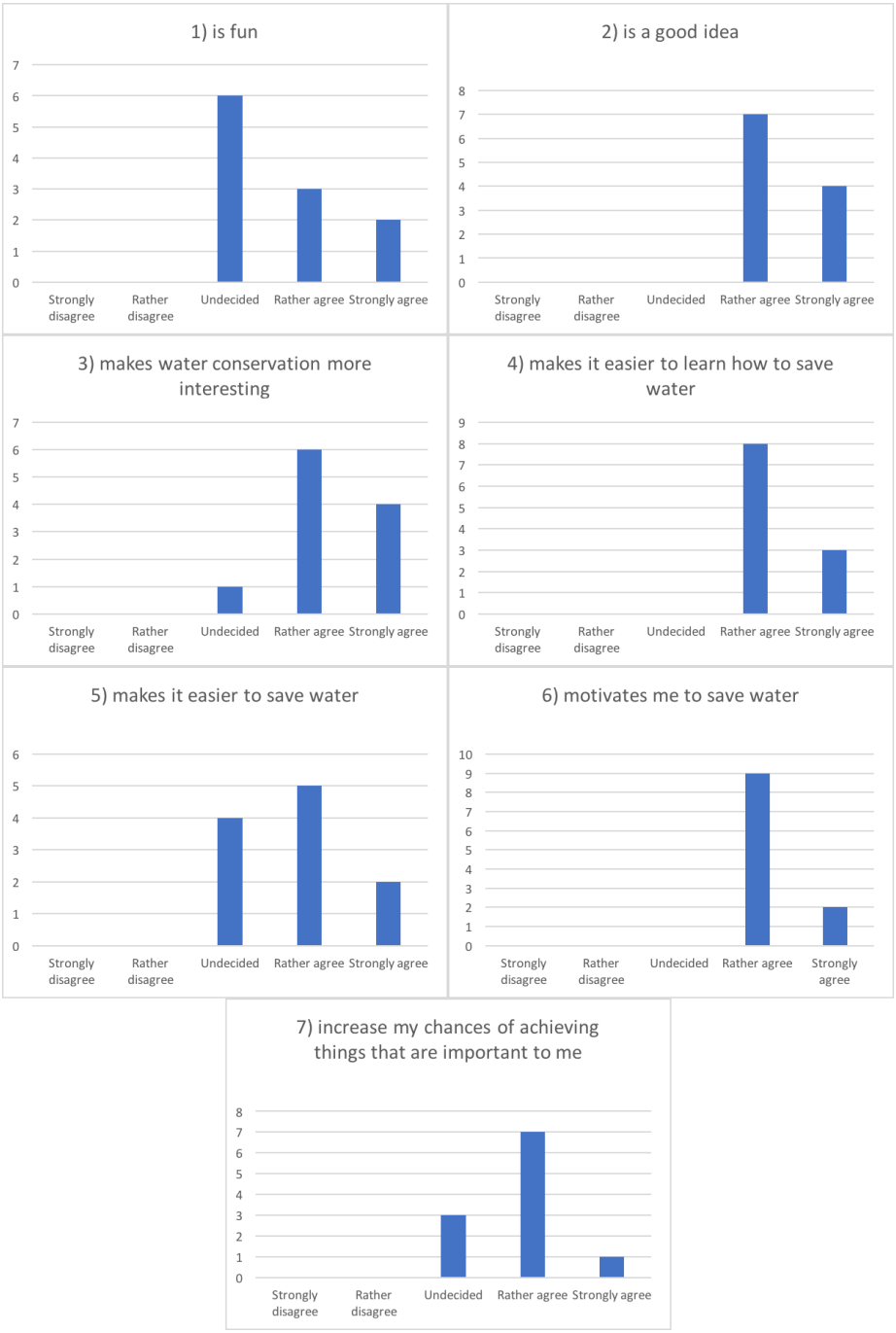

Figure 83: UTAUT: Attitude toward technology (mobile)

The majority of the users rather agree that the mobile version of the SmartH2O

application is a good idea (Figure 83-2), making easier saving water (Figure 83-4,5), a lot said that it motivates them to do so (Figure 83-6). In the overall, even those results are quite positive (Figure 83).

Hedonic and Pragmatic quality (mobile version)
Hedonic and pragmatic quality was measured using the *AttrakDiff2* questionnaire [29], in which hedonic quality (stimulation) and pragmatic quality were measured. The results are displayed below (Figure 84).

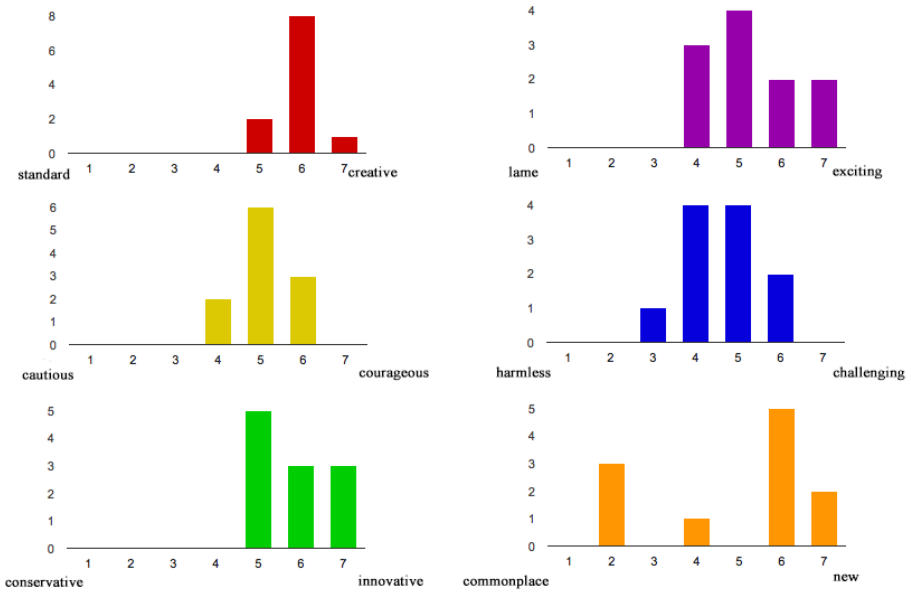

Figure 84: Hedonic quality (stimulation) results (mobile)

Hedonic quality (stimulation) received on average a score of 5,18 on a scale 1-7, which is considered as stimulating. The innovativeness and creativity of the SmartH2O application were highly rated, thus not considered very new. The alpha testers found the app stimulating to use, according to those results, but a little bit challenging. The overall result is positive, because the mobile version of SmartH2O application is born to help the final user to increase his awareness on water consumption in a fun way, in order to change indeed his behavior.
The pragmatic quality results are displayed below (Figure 85).

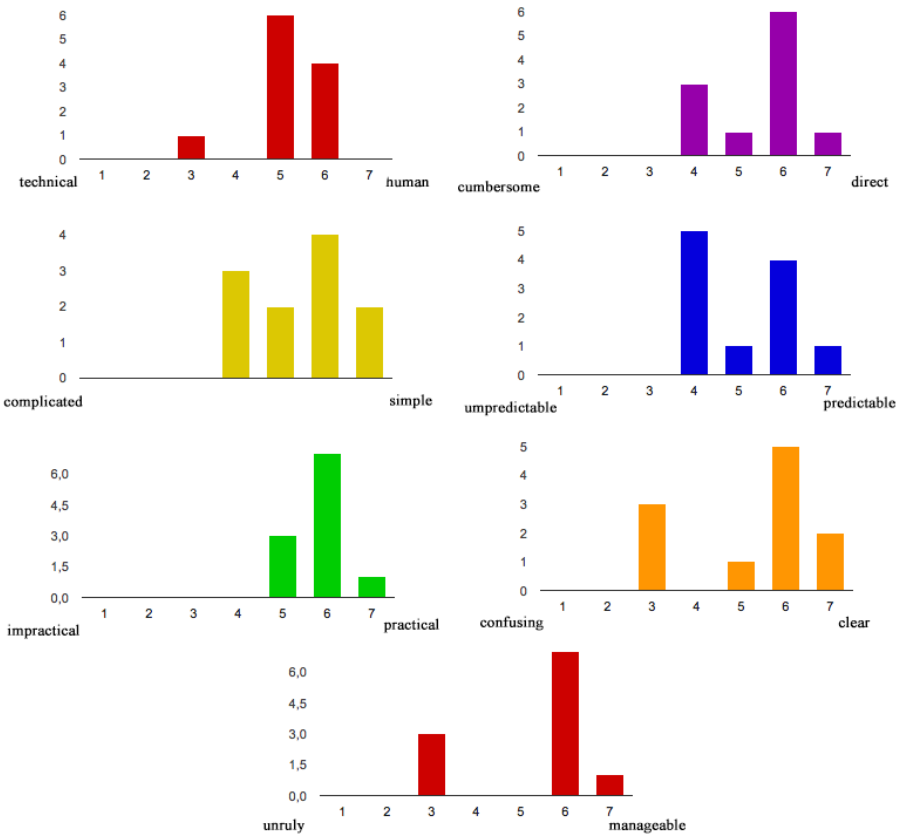

Figure 85: Pragmatic quality results (mobile)

Pragmatic quality scores are also rather positive. The balance between pragmatic quality and hedonic quality suggests that alpha testers are both stimulated by the innovative nature of the app, and able to derive utilitarian value from it. The application is resulted simple, usable and clear, even if in a not dominant way. Some users are quite uncertain about those feature, leading to heterogeneous results.
These results are encouraging since the application would be a companion of the already know web portal and should provide an additional help in water consumption change behavior.

Consumption visualization and notifications (mobile version)
In this section, there will be an overview on the results collected on some feature of the mobile application that are slightly different from the web platform: water consumption visualization, goal setting, alerts and notifications. To assess their effectiveness, alpha testers were asked if they thought about water consumption more often than before, felt more motivated to save water and to use the app.

Results below (Figure 86).

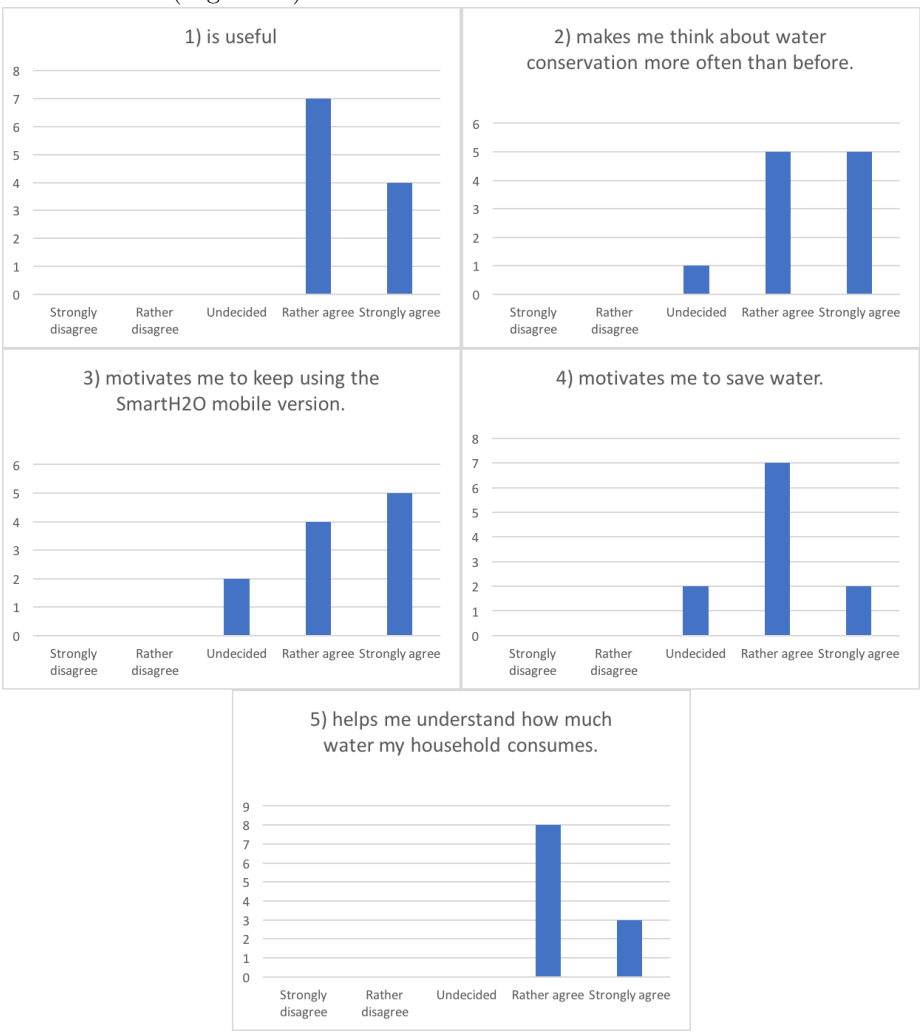

Figure 86: Motivational effect of water consumption chart (mobile)

Nearly all respondents stated that the water consumption chart and the water consumption overview made them think about water consumption more often but the majority only rather agreed with this (Figure 86-2). Almost the same also agreed that the chart and overview motivate them to save water (Figure 86-4).

Again, the majority thinks that the chart motivated the application usage, rather agreeing that the chart is useful and helping (Figure 86-1). Overall, this is a very positive assessment, meaning that the mobile app's UI helps in creating continuity with the portal and making the use of the app useful.

In the end, the vast majority found the water consumption chart quite effective

towards understanding their own consumption (Figure 86-5).

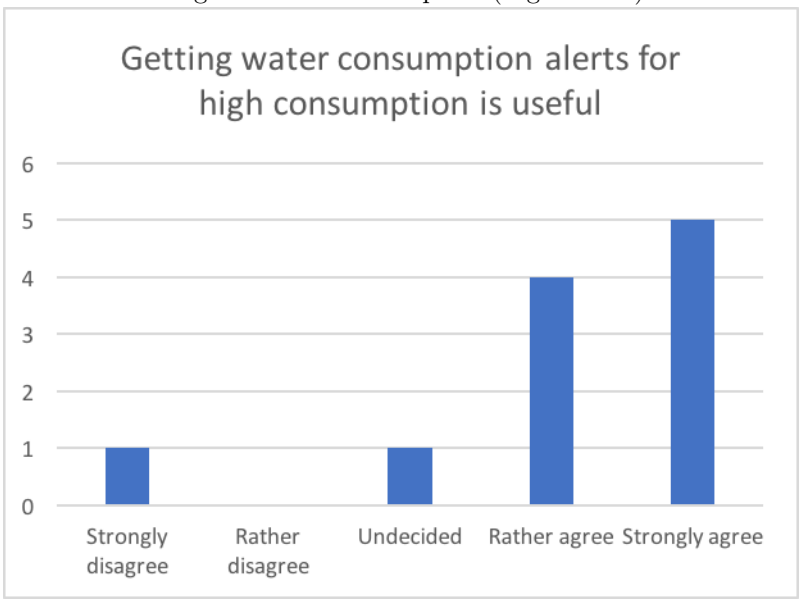

Figure 87: Motivational effect of water consumption alert (mobile)

Water consumption alerts were found useful by a vast majority of people, even if one strongly disagree with that, as can be seen in the graph above (Figure 87). The app proves to be a strong companion for the already assessed incentive – from the portal's results – of the consumption alerts for people to use smart metering technology and accompanying visualizations and services. Consumption goals were also assessed as very useful by nearly all users.
This is emphasized by the positive responses towards the incentive effect of the consumption goals. Overall, a vast majority agreed, in different ways, that the consumption goals set in the mobile app made them think more about water conservation than before (see Figure 88-2) and motivated them to save water (see Figure 88-4). They also stated that goals motivated them to use the SmartH2O mobile app (Figure 88-3), with some indecisive responses.

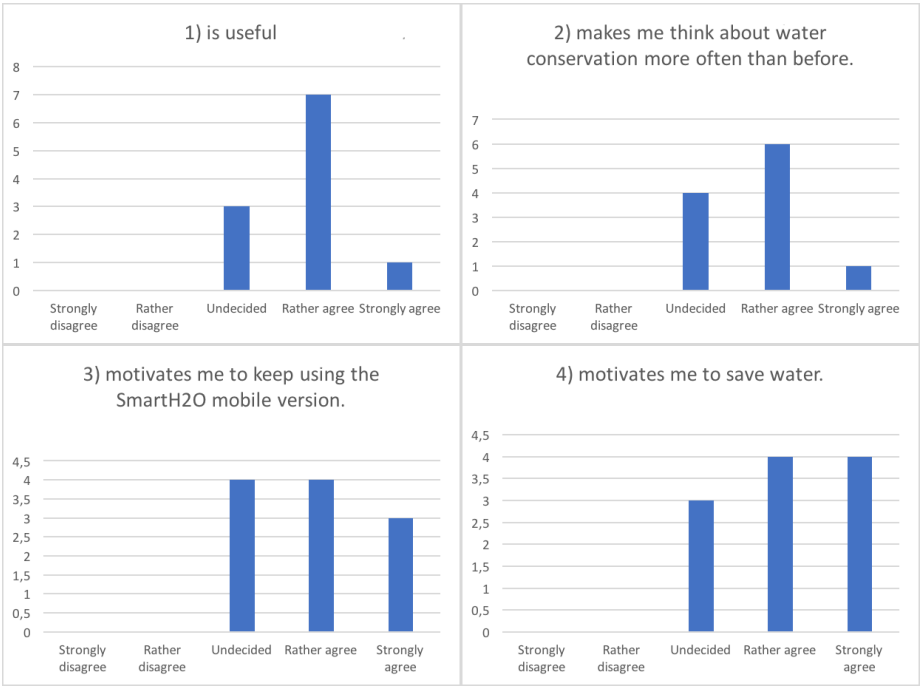

Figure 88: Motivational effect of goal setting (mobile)

In terms of the notification management, there are different points of view. Almost half of the alpha testers find receiving push notifications useful. In details, a lot of them strongly agreed that notifications make them think about water conservation more than before, with the same number undecided about that (Figure 89-2). The same can be said for the motivation that notifications aim in using the mobile app (Figure 89-3) and in saving water (Figure 89-4). The other half users are undecided about the usefulness of the push notification, with some rather disagreeing with that.

Push notification are thought as a strong incentive for keeping the users' interest in water consumption active, but this kind of effectiveness can only be seen after some time has passed from the first use of the application. Alpha testers, maybe, have not seen a real usage of the notification because they're not using the application on a regular basis.

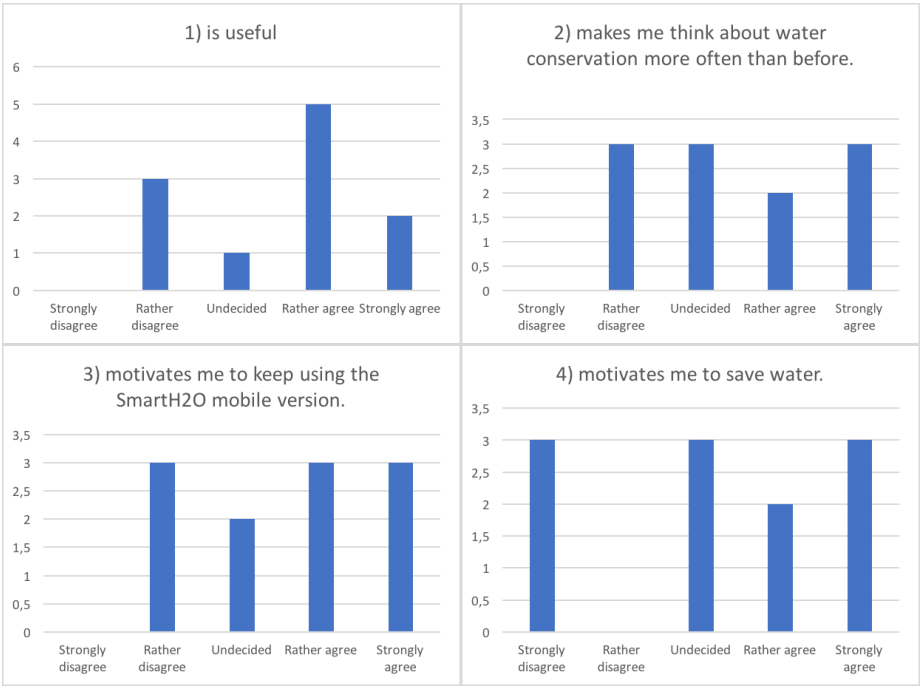

Figure 89: Motivational effect of push notifications (mobile)

6.5 Comparison between web and mobile consumer applications

Questionnaire results have demonstrated that alpha testers feel almost the same with respect to the web and the mobile version of the mobile application. This could mean that the SmartH2O app is really seen as a companion of the web portal, feeling the continuity between them, making the usage of the mobile application as simple as the one of the web portal. The real profit is done by the fact that the mobile application is felt more motivating (Figure 90-2), fun (Figure 90-1) and useful in terms of achieving things important for the user (Figure 90-3).

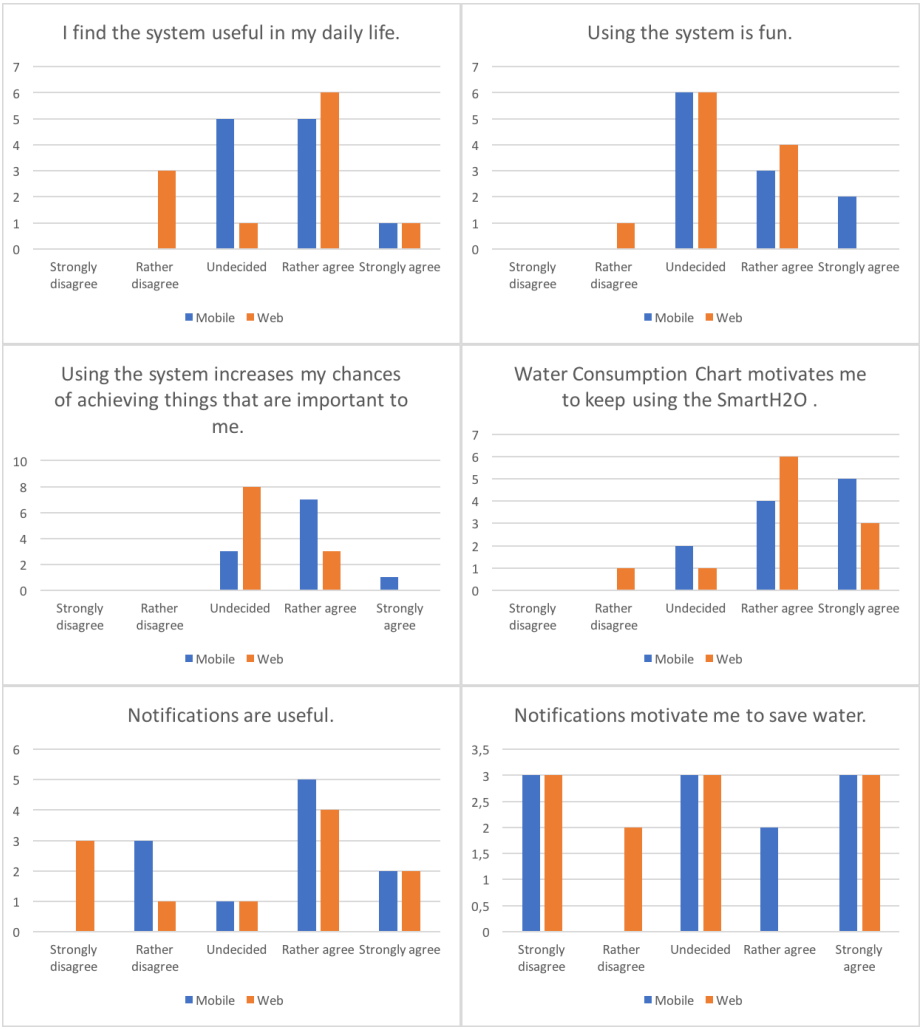

Figure 90: Indirect comparison between user's attitude towards web and mobile versions

Graphs above represent the results of the same questions asked for both the web and the mobile portal, making simple the comparison between them. It is clear that, taking into account the parity of results gained for other questions, that the mobile application is perceived better in terms of usefulness with respect of the web portal. At the end, questions about a direct comparison between the two versions were asked to the alpha testers. Results reported in Figure 91.

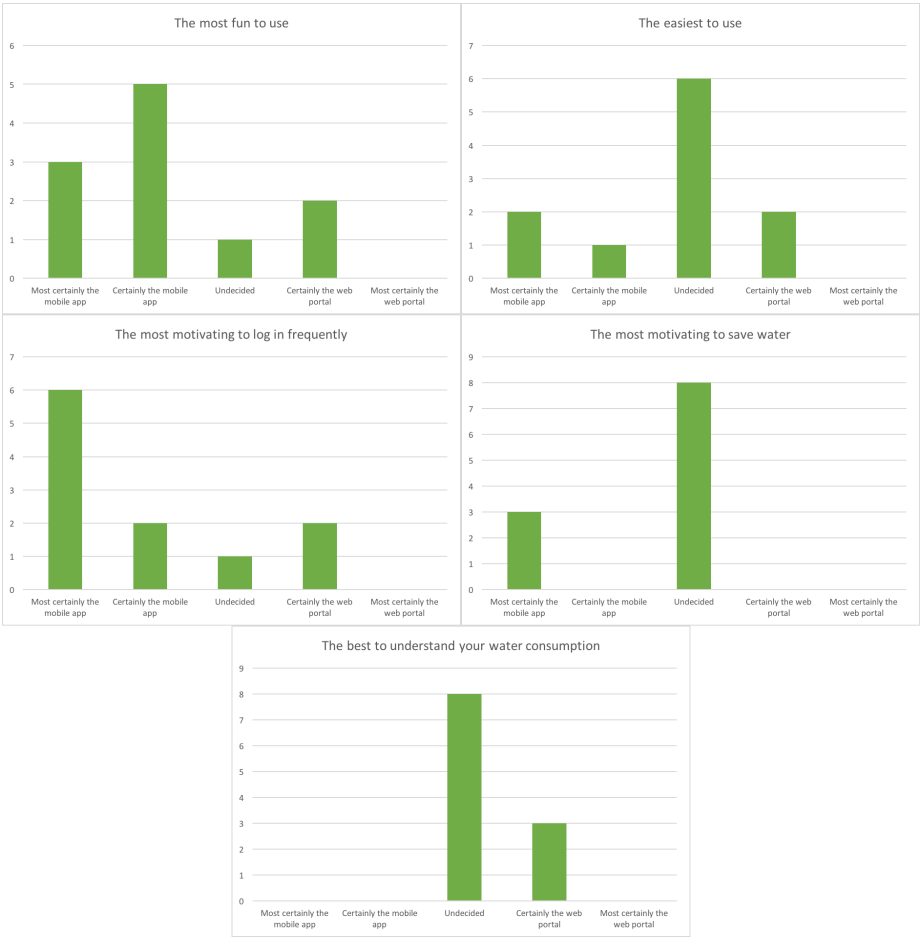

Figure 91: Direct comparison between user's attitude towards web and mobile versions

As can be seen, the most majority prefers the mobile version as being the most fun to use (Figure 91-1) and the most motivating in logging in frequently (Figure 91-3). Other graph shows a division between the mobile-enthusiastic and the uncertain, still making the preference going towards the use of the mobile version of the app. The web portal is felt as the best for understanding own water consumption only by few people, while the majority is uncertain. Those results, still being gained from a small set of users, are very positive in terms of efficacy of the mobile application as an instrument aimed to the change of behavior in water consumption.

6.6 Effectiveness of behavioral change stimuli

In this subchapter, data from the user's consumption after the registration to the portal has been retrieved and compared with old consumption data, to check

whether the utilization of the SmartH2O platform has helped in saving water, raising the awareness on water consumption, which is the goals of this project and thesis.

6.6.1 Swiss Case

In order to characterize the users in terms of their water consumption volumes, smart meter measurements collected from the moment of the smart meter installation up to October 31st 2015 (i.e. when the second version of the basic portal was released) have been used for the baseline computation. The date when the smart meter was installed at the user's premises varied from user to user in a range between December 2014 and September 2015. From that moment on, consumption data began to be collected by the SES metering data collection infrastructure. It must be noticed that this data is just useful to build a preliminary analysis about the trend of the impact of SmartH2O application, but it doesn't take into account other important factors like seasonal variations on the availability of water, then the number of users is too small to build up an accurate analysis.
The baseline has then been compared to the average daily consumption computed over data spanning from November 1st 2015 to February 6th 2016. According to their average consumption values, users have been classified as low (consumption until 0.4 m^3), low/medium (consumption between 0,5 and 1 m^3), medium/high (consumption between 1 and 2.5 m^3) or high (consumption above 2.5 m^3) consumers. Finally, the consumption reduction percentage in comparison to the baseline value has been calculated .
Results demonstrate that the average consumption reduction varies per consumption class, ranging from 23% to 41%, with an average reduction of 27.5% across consumption classes (note that the high-consuming class only contains two users). It can be seen from the graph (Figure 92) that there is a large difference between users. This is probably due to a self- selection effect: users most interested in water efficiency – with low water consumption levels – are more likely to join the platform in an early phase than users with little awareness and high consumption levels.
An even more accurate quantification of the consumption reduction due to the platform usage will be provided as soon as the mobile version of the SmartH2O application would be released, when validation data over both the version will be available.
The results are depicted in Figure 92.

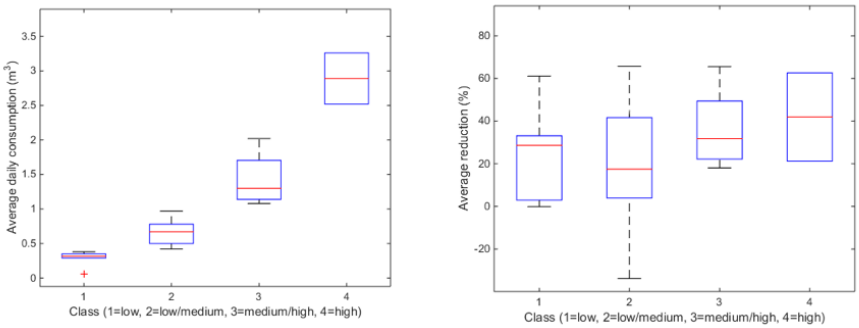

Figure 92: Average consumption by classes (left) and average consumption reduction by classes (right) (Swiss pilot) [85].

As can be seen from Figure 92 (right), the average consumption reductions vary per class, with the highest consumption reductions achieved for the high-consuming households and the medium-high consumers.
Differences between consumption classes might be explained from differences in awareness and attitudes towards water consumption. More investigations should be done on this topic.
Even though the results are promising in terms of the water consumption reduction percentages, a more detailed analysis of water consumption reduction results can only be done once a longer period of smart metered water consumption data and platform usage data is available. Nevertheless, the first results are positive when compared against the target level of the associated KPI of the SmartH2O project (5% reduction), also given the fact that the peak summer period – during which most savings can be achieved – has not yet been measured.

6.6.2 Spanish Case

Valencian users have been using smart meters since 2014. Then, a clear calculation of the base value (the average consumption since the first installation of smart meters) has been possible. Since in the first release of the application (first quarter of 2016) a total of 389 users have been registered to the portal, a first evaluation of the effects of SmartH2O could be done, even if a complete year of metering is not passed yet at the time of this thesis. It must be noticed that this data is just useful to build a preliminary analysis about the trend of the impact of SmartH2O application, but it doesn't take into account other important factors like seasonal variations on the availability of water or a strong correlation between the use of the portal and the effective decrease of water consumption.
From the data collected, 46 outliers have been found and excluded from this computation. Outliers have been defined as users having null baseline value or consumption, maybe due in errors in their smart metering. Others have baseline or consumption above 0.7 m^3, that is a threshold used to consider

users consuming really too much to be taken into account.
Similar to the Swiss case, users have been classified, according to their average consumption values, as low (consumption until 0.15 m^3), low/medium (consumption between 0.15 and 0.25 m^3), medium/high (consumption between 0.25 and 0.4 m^3) or high (consumption above 0.4 m^3) consumers. The baseline has then been compared to the average daily consumption computed over data spanning from the registration date of the portal of each user to November 22nd 2016.
It can be seen from the graph (Figure 93) that there is a large difference between users. Results demonstrate that the average consumption reduction varies per consumption class, as the Swiss case, ranging from 6.8% to 9.3%, with only a 3% of consumption reduction of the low consumption class. That could be derived by the fact that such users consume really a small amount of water and a real reduction in water consumption with the actual consumption after the registration of the portal is hard to achieve.

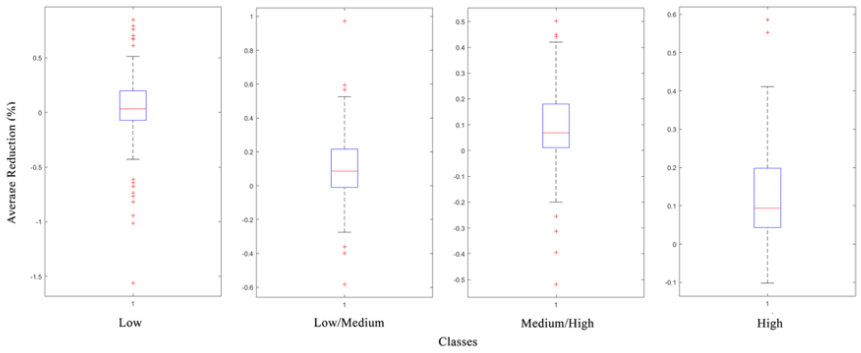

Figure 93: Average consumption reduction by consumption class (Spanish pilot)

Overall, on a total of 343 users used to build this evaluation, the percentage of the total water saved is about 6.9% (Figure 94). That is a good achievement at this early point of the evaluation, and the expectation could be very high once the mobile version is released.

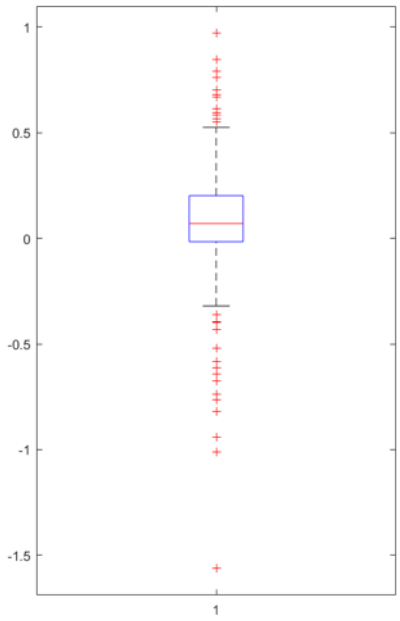

Figure 94: Average consumption reduction over the total number of users (Spanish pilot)

An even more accurate quantification of the consumption reduction due to the platform usage will be provided as soon as the mobile version of the SmartH2O application would be released, when validation data over both the version will be available, for both the pilots. In addition, for the Spanish plot, further investigation on this analysis will be done as soon as more data is available (possibly a full year of consumption monitor since the registration of each user to the portal). It has been planned, then, to apply a different methodology to calculate consumption reduction, taking into account the control group's – a group of people that are not registered to the platform - and the treatment group's (e.g. the SmartH2O app's users) consumptions to be able to attribute effects on awareness and/or water consumption to the SmartH2O platform. Then, with more time elapsed, a deeper analysis can be done retrieving such information in different seasons, in order to be able to exclude effects of exogenous circumstances, such as seasonal variations in the availability of water [85].

7 Conclusion and future work

Water conservation is important because it keeps water clean and pure and conserves the environment. It is also important because the supply of water is not endless. About 2 percent of Earth's fresh water is locked in glaciers and ice caps, while 97 percent is salt water. Therefore, only 1 percent of water on Earth is available for drinking [94]. Awareness on such a delicate topic is fundamental to save water and to protect our environment and our specie.
The SmartH2O project's aim is to link water utilities to their customers to provide a deep understanding of their consumptions and behavior on water saving, helping them to increase their awareness on water consumption until their behavior itself could change in a more sustainable one. To do so, a deep study on the motivational theories and behavioral mechanics has been done.
This thesis has provided the implementation of the architecture and components of the mobile version of the SmartH2O social awareness application. The overall architecture of the SmartH2O platform has been specified in terms of the major components, such as data stores, user interfaces, and system interfaces, as well as the principal control and data flows among them. Once understood all the logic that stands behind the Android application, i.e. server side, the app components have been examined at depth, which permitted to identify clearly the supported use cases, and the required interfaces and message management.
The study of the motivational theories and behavioral change mechanisms has led to all the implementation choice described in this thesis, especially for the notification management and the UI design.
The specification of the architecture and the mobile capabilities will be refined as the project progresses, after the first analysis of the data collected from the beta testing of the application.
Real-world deployment and validation of the SmartH2O approach is a crucial part of the project. This thesis has detailed the first validation results, relative to the web portal: the evaluation of the portal as well as the baseline collection results for both case studies.
In terms of user acceptance, participants of the trials positively evaluated the utilitarian value of the SmartH2O web portal (e.g. performance expectancy, see 2.2.3) and stated a positive attitude towards the technology in general. Also, most success criteria that were introduced during the choices of methodologies to be adopted (see Chapter 2.5) and requirements (see Chapter 4.1) received positive ratings, including usefulness of water saving tips and water consumption visualizations, and also the extent to which users are encouraged to think more about their water consumption by inspecting consumption feedback was quite successful.
In the upcoming trials, particular emphasis will be placed on the validation of the mobile version of SmartH2O, as a way to incentivize even more users to engage with water consumption feedback, and to start contemplating their water consumption, providing an app that can be used whenever and wherever the user wants. For this purpose, an early evaluation has been done using data grabbed from a questionnaire that has been provided to alpha testers of the

application. The results are just a start point to understand the impact that the introduction of the mobile app can lead to.

7.1 Future Work

SmartH2O applications, both the web portal and the mobile app, are working prototypes that still need some improvements. Consumers and utility managers require more functionalities to perform their task, for example utilities are able to track the current consumption, but prediction of future consumption is still needed. Machine learning techniques could be applied to predict the future consumption trend, helping taking preventive actions – instead of reactive ones – and the accuracy can be increased according to the study of the comparison between real consumption and predicted one. This could be useful also to identify factors that admins may be overlooking while planning for the future.
By installing water meters in key points of the water grid and periodically compare their flows, a leakage and failure detection system can be build, permitting to understand which segments of the grid are getting less water that they should. Unfortunately, there is a strong dependency on the infrastructure availability that might derive in cost and planning, a deep analysis has to be done by the water utility itself.
On the mobile application, a lot of improvements can be done, starting for the social aspects of the experience. In contrast of the web portal, the social part is still missing. A Social Networks sharing button could be added in order to let the users being able to share their rank on the leaderboard, the badge won or the tips read. Then, all the social aspects of the entire project can be refined on adding other social and challenging elements, typical of a social game. For example, a player vs. player water saving challenge could be introduced, where players would be able to challenge each other to weekly or monthly challenges to reduce as much as possible their consumption, that could increase engagement and increase even more water saving.
To enhance the social dimension of the game, introducing player comments on the leaderboard could result in an increment of the page traffic, but this kind of functionality has to be deeply analyze since it might require moderation and oversight to prevent abusive or aggressive user to discourage other users. Similar to comments, also messages can be implemented: a dynamic chat can be build up upon a neighborhood, where users can talk to their neighbors about water consumption topics, but that could issue security and privacy problems.
One of the main aspect of the SmartH2O project is the possibility to analyze data in order to better understand the users' behavior on data consumption and to modify the adopted solutions to incentivize even better consumers to save water. Such results can be obtained by querying the database of the platform, retrieving consumption data and other useful information such as the number of logins, the most visualized sections, etc. At the beginning of the project, the few knowledges about the effort this calculation could lead and the actual technological status lead the developers to the decision to use relational DB like SQL and others. Nowadays, doing queries on large timestamps of water

readings and analyzing those data to create a statistical path, have been a though work. To improve the performances and the quality of the data collected, two different approaches can be taken in the future, in details two different models of databases can be taken into account.
The first is *Apache Cassandra*, a database with linear scalability and proven fault-tolerance due to the fact that data is automatically replicated to multiple nodes across multiple datacenters. It lies on commodity hardware or cloud infrastructure, making it the perfect platform for mission-critical data, providing also lower access latency [80]. The idea is to use Cassandra as a storage for temporal data, with the objective to retrain data without losses, with an easy horizontal-scalability.
Another possibility is the use of *InfluxDB* by *Influxdata*, that is a time series database built from the ground up to handle high write and query loads. It is meant to be used as a backing store for any use case involving large amounts of timestamped data, like our case, including DevOps monitoring, application metrics, IoT sensor data, and real-time analytics [82]. Implementing such a database would not be a hard work, due to its SQL-like query language that allows the project's developers to re-use their knowledge about SQL, in addition it has plugins for data ingestion protocols and APIs to perform queries in HTTP(S). From the administrational point of view, it has also a built-in web admin interface. It is very useful to create statistical queries, but the basic version has not the redundancy of data and the linear scalability as a default feature.
A number of ideas for the SmartH2O project are still in development, the study on the feasibility and the cost of each of that will lead to an implementation – or not – of such functionalities in the web portal. The mobile version will be updated accordingly, creating a continuity of experience and providing the most value to the people and companies, bringing the project closer to accomplish its goals in helping on water saving and in behavioral change on water consumption.

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Appendix A – Questionnaires

A.1 Mobile and Web Comparison questionnaire items

In the table below, the items catalogued that were used for the comparison questionnaires in the early validation of the SmartH2O mobile version. All the questions in the table, except for the final comparison one, are asked both for the mobile version and the web version of the application.

Table 29: Appendix A – Mobile and Web comparison Questionnaire

Construct	Item no.	Item	Measurement	Source
UTAUT – Performance expectancy	1	I find the Smart H20 portal useful in my daily life.	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	[28]
	2	Using the Smart H20 portal increases my chances of achieving things that are important to me.	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	
UTAUT – Effort expectancy	1	Learning how to use the SmartH2O portal is easy for me.	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	[28]
	2	My interaction with the Smart H20 portal is clear and understandable.	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	
	3	I find the Smart H20 portal easy to use.	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	
	4	It is easy for me to become skillful at using the SmartH2O portal.	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	
UTAUT-Attitude towards technology	1	Using the Smart H2O portal is a bad/good idea	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	[28]
	2	The system makes water conservation more interesting.	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	

Construct	Item no.	Item	Measurement	Source
	3	Working with the system is fun.	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	
	4	The system makes it easier to learn how to save water.	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	
	5	I like working with the system.	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	
	6	The system motivates me to save water	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	
	7	The system makes it easier to save water.	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	
Hedonic quality (stimulation)	1	Standard—creative	7-point semantical differential	[29]
	2	Cautious—courageous	7-point semantical differential	
	3	Conservative—innovative	7-point semantical differential	
	4	Lame—exciting	7-point semantical differential	
	5	Harmless—challenging	7-point semantical differential	
	6	Commonplace—new	7-point semantical differential	
Pragmatic quality	1	Technical—human	7-point semantical differential	[29]
	2	Complicated—simple	7-point semantical differential	
	3	Impractical—practical	7-point semantical differential	
	4	Cumbersome – direct	7-point semantical differential	
	5	Unpredictable—predictable	7-point semantical differential	
	6	Confusing—clear	7-point semantical differential	

Construct	Item no.	Item	Measurement	Source
	7	Unruly—manageable	7-point semantical differential	
The water consumption chart	1	is useful	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	-
	2	makes me think about water conservation more often than before	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	
	3	motivates me to keep using the system	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	
	4	motivates me to save water	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	
	5	helps me understand how much water my household consumes	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	
Being able to set my own goals	1	is useful	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	-
	2	makes me think about water conservation more often than before	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	
	3	motivates me to keep using the system	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	
	4	motivates me to save water	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	
Consumption alerts	1	Getting water consumption alerts for high consumption on the web portal is useful.	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	-
The notifications	1	are useful	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	-

Construct	Item no.	Item	Measurement	Source
	2	make me think about water conservation more often than before	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	
	3	motivate me to keep using the system	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	
	4	motivated me to save water	5-point Likert scale (1=Strongly disagree; 5=Strongly agree)	
COMPARISON: Which SmartH2O version do you like best on each of the following aspects? Which version is…	1	most fun to use	5-point Likert scale (1=Most certainly the mobile app; 5=Most certainly the web portal)	-
	2	easiest to use	5-point Likert scale (1=Most certainly the mobile app; 5=Most certainly the web portal)	
	3	most motivating to log in frequently	5-point Likert scale (1=Most certainly the mobile app; 5=Most certainly the web portal)	
	4	best to understand your water consumption	5-point Likert scale (1=Most certainly the mobile app; 5=Most certainly the web portal)	
	5	most motivating to save water	5-point Likert scale (1=Most certainly the mobile app; 5=Most certainly the web portal)	

A.2 Web portal validation questionnaire items

In the table below the items catalogued that were used for the different questionnaires in the validation of the web portal of SmartH2O.

Table 31: Appendix A – Web Portal validation Questionnaire

Construct	No.	Item	Measurement	Source	Basic p. Q.	Sign-up Q.	Up. Q.
UTAUT – Performance expectancy	1	I find the Smart H20 portal useful in my daily life.	7-point Likert scale (1=Strongly disagree; 7=Strongly agree)	[28]	Y	N	N
	2	Using the Smart H20 portal increases my chances of achieving things that are important to me.	7-point Likert scale (1=Strongly disagree; 7=Strongly agree)				
UTAUT – Effort expectancy	1	Learning how to use the SmartH2O portal is easy for me.	7-point Likert scale (1=Strongly disagree; 7=Strongly agree)	[28]	Y	N	N
	2	My interaction with the Smart H20 portal is clear and understandable.	7-point Likert scale (1=Strongly disagree; 7=Strongly agree)				
	3	I find the Smart H20 portal easy to use.	7-point Likert scale (1=Strongly disagree; 7=Strongly agree)				
	4	It is easy for me to become skilful at using the SmartH2O portal.	7-point Likert scale (1=Strongly disagree; 7=Strongly agree)				
UTAUT-Attitude towards	1	Using the Smart H2O portal is a bad/good idea	7-point Likert scale (1=Strongly disagree; 7=Strongly agree)	[28]	Y	N	Y
	2	The system makes work more interesting.	7-point Likert scale (1=Strongly disagree; 7=Strongly agree)				
	3	Working with the system is fun.	7-point Likert scale (1=Strongly disagree; 7=Strongly agree)				

Construct	No.	Item	Measurement	Source	Basic p. Q.	Sign-up Q.	Up. Q.
	4	I like working with the system.	7-point Likert scale (1=Strongly disagree; 7=Strongly agree)				
Hedonic quality (stimulation)	1	Typical—original	7-point semantical differential	[29]	Y	N	N
	2	Standard—creative	7-point semantical differential				
	3	Cautious—courageous	7-point semantical differential				
	4	Conservative—innovative	7-point semantical differential				
	5	Lame—exciting	7-point semantical differential				
	6	Easy—challenging	7-point semantical differential				
	7	Commonplace—new	7-point semantical differential				
Pragmatic quality	1	Technical—human	7-point semantical differential	[29]	Y	N	N
	2	Complicated—simple	7-point semantical differential				
	3	Impractical—practical	7-point semantical differential				
	4	Cumbersome – direct	7-point semantical differential				
	5	Unpredictable—predictable	7-point semantical differential				
	6	Confusing—clear	7-point semantical differential				
	7	Unruly—manageable	7-point semantical differential				
Attitude towards water saving	1	Engaging in everyday actions to save water around the house and garden is: extremely bad/extremely good; extremely harmful/extremely beneficial; extremely worthless/extremely valuable;	7-point semantical differential	[57]	Y	Y	N
	2						
	3						
	4						

Construct	No.	Item	Measurement	Source	Basic p. Q.	Sign-up Q.	Up. Q.
	5	extremely unpleasant/ extremely pleasant					
Subjective norm	1	It is expected of me that I save water around the house and garden	7-point Likert scale (1=Strongly disagree; 7=Strongly agree)	[57]	Y	Y	N
	2	I feel like there is social pressure to save water around the house and garden	7-point Likert scale (1=Strongly disagree; 7=Strongly agree)				
	3	People who are important to me want me to save water around the house and garden	7-point Likert scale (1=Strongly disagree; 7=Strongly agree)				
Perc. beh. control	1	I am confident that I could save water around the house and garden if I wanted to,	7-point Likert scale (1=Strongly disagree; 7=Strongly agree)	[57]	Y	Y	N
Behavioral intention to save water	1	I expect I will engage in everyday actions to save water around the house and garden in the next six months	7-point Likert scale (1=Strongly disagree; 7=Strongly agree)	[57]	Y	Y	N
	2	I intend to engage in everyday actions to save water around the house and garden in the next six months,	7-point Likert scale (1=Strongly disagree; 7=Strongly agree)				

Construct	No.	Item	Measurement	Source	Basic p. Q.	Sign-up Q.	Up. Q.
	3	I want to engage in everyday actions to save water around the house and garden in the next six months	7-point Likert scale (1=Strongly disagree; 7=Strongly agree)				
Behavioral beliefs (utilitarian)	1	There is much water in [area name]. We just have to conduct it to our cities	Four-point Likert scale (1= completely disagree; 4=completely agree)	[24]	Y	Y	N
	2	Science surely will solve the problem of water scarcity	Four-point Likert scale (1= completely disagree; 4=completely agree)				
	3	Drinkable water is an unlimited resource	Four-point Likert scale (1= completely disagree; 4=completely agree)				
	4	Drinkable water will exhaust very soon if we do not save it	Four-point Likert scale (1= completely disagree; 4=completely agree)				
Beh. Beliefs (ecological)	5	A way of preventing water exhaustion is using it when absolutely necessary	Four-point Likert scale (1= completely disagree; 4=completely agree)				
Usefulness		How useful or useless is the water consumption chart/the water consumption overview for you?	Five-point Likert scale (1=complete disagree; 5=completely agree)	Success criteria	Y	N	Y
		How useful are the water saving tips for you?	Five-point Likert scale (1=very useless; 5=very useful)		(b.p. v1)		(b.p. v2)
Comprehension		I can understand from the chart/from the overview how much water my household consumes over time	Seven-point Likert scale (1=complete disagree; 7=completely agree)		Y	N	(basis: basic portal v2)

Construct No.	Item	Measurement	Source	Basic p. Q.	Sign-up Q.	Up. Q.
	How clear are the following options to adjust the display of the water consumption chart? - Possibility to adjust the displayed data to days, weeks, or months - Possibility to display your own daily average - Possibility to display neighbourhood average - Opening hourly water consumption charts - Sliders to adjust the timespan of the displayed data	Five-point Likert scale (1=very unclear; 5=very clear + 'Did not use this option (yet)')		(b.p. v1)		
Ease of use	How easy or difficult was it for you to use the water consumption chart? How easy or difficult was it for you to take notice of the water saving tips?	Five-point Likert scale (1=complete disagree; 5=completely agree) Five-point Likert scale (1=very difficult; 5=very easy)		(b.p. v1)	N	(b.p. v2)
Perception of awareness increase	Please indicate to what extent you agree with the following statement: "The water conservation tips make me think about water consumption more often than before."	Seven-point Likert scale (1=complete disagree; 7=completely agree)		(basis: basic portal v1)	N	(b.p. v2)

Construct	No.	Item	Measurement	Source	Basic p. Q.	Sign-up Q.	Up. Q.
		To what extent were you able to put the water saving tips in practice?	Five-point Likert scale (1=to a very small extent; 5=to a very large extent)				
-	-	User reference ID (for tracking purposes)			Y	Y	Y
Awareness	1	How much water do you think you consume compared to the average consumption of similar households in your area:	a. Much more b. Somewhat more c. Same as average d. Somewhat less e. Much less	Pricing questionnaire	Y	Y	N
Awareness	2	Which of the following activities do you think consumes the most water on a monthly basis?	a. Bath b. Shower c. Washing machine d. WC e. Garden irrigation f. Dishwasher		Y	Y	N
-	-	Since when do you have an account for the Smart H20 portal?	a. Tab Five-points scale		Y	N	Y
-	-	How many adults are in your household?	Number		Y	Y	N
-	-	How many children are in your household?	Number		Y	Y	N
-	-	What kind of house do you live in?	House / Apartment / other		Y	Y	N

Construct	No.	Item	Measurement	Source	Basic p. Q.	Sign-up Q.	Up. Q.
-	-	Educational level		Intern. Standard Classification of Education	Y	Y	N
Personal innovativeness	1	If I heard about a new information technology, I would look for ways to experiment with it.	Seven-point Likert scale (1=Strongly disagree; 7=strongly agree)	[34]	Y	Y	N