INCENTIVE MODELS AND ALGORITHMS

SmartH2O

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Executive Summary

This document is the Deliverable **D4.3, INCENTIVE MODELS AND ALGORITHMS**, which, according to the DoW has the following goals:

D4.3) Incentive models and algorithms: This deliverable contains: a review of motivational models in games and persuasive applications; a survey of incentive models and algorithms; a review of specific incentive models and tools used to stimulate user involvement and cooperation in executing smart water management tasks (e.g. validating water consumption data); the selection, implementation and testing of incentive models and algorithms: based on D4.2 the models and algorithms more appropriate for the SmartH2Oend-users will be implemented in the client platform and back-end; it also reports on testing of incentive models and algorithms: the incentive models and algorithms are tested with the end-user and data e feedbacks are collected.

The content of the deliverable is organised as follows:

- Section 1 introduces the rationale of the deliverable, which is the outcome of the design and implementation of two pilots with distinctive features.
- Section 2 presents the SmartH2O behavioural change approach, with a specific focus on user's motivation as a critical success factor for water-related behavioural change systems
- Section 3 surveys incentive models and algorithms from the literature, to set the background of the concrete incentive mechanics implemented in SmartH2O.
- Section 4 turns theory into practice, by illustrating the selection and implementation of incentive models and algorithms specific for the SmartH2O pilots.
- Section 5 reports on the preliminary definition of a methodology for testing of incentive models and algorithms in SmartH2O, which comprises both a priori simulation and a posteriori assessment.
- Section 6 concludes with an outlook on the future work.

The most relevant contribution of this deliverable is the in-depth study, design and implementation of incentives for water consumers in different deployment scenarios. The literature about incentives for sustainable water consumption is extremely scarce. There is very little guidance on the definition of an appropriate mix of incentive stimuli tailored to a specific customer base and sustainability campaign.

SmartH2Ohas invested a large effort in designing and implementing a very general incentive framework, which can be used to deliver a very broad set of stimuli, in a technically and communication-wise coherent manner. This deliverable reports on the design rationale of such incentive system (the Gamification Engine in the SmartH2O terminology) and of the rewarding rules embedded into it.

This deliverable D4.3 relates to other deliverables of the same period as follows:

- D3.4 Final user behaviour models and ABM simulator: this deliverable sets the scheme of a diffusion model that can be used to evaluate the impact of stimuli to the behaviour change of users; this model is used in WP4 and applied to the design and implementation of the incentive policies. Specifically, results from WP3 have been used to support the design of the incentive systems of the pilots, to enable the estimation of the behaviour of users exposed to the incentive policies under design, and to assess the potential number of "winners" and thus the impact of incentives on the distribution of rewards and thus on the budget. Section 5 of this deliverable reports on this fundamental application of the simulation models.
- D6.4 Platform Implementation and Integration - second prototype: this deliverable is a software package, which contains the actual implementation of the incentive mechanism and user interfaces described in this deliverable.
- D7.2 Validation report (SES): This deliverable reports on the deployment of the SmartH2Oplatform (inclusive of the incentive models) in the two pilots (run by SES in Switzerland and by EMIVASA in Spain) and sets the validation approach that will be followed to compute all the project KPIs, including those directly connected to the

effectiveness of the incentives for engaging and retaining people in the SmartH2O platform.

This deliverable is also correlated with the document “GAMIFICATION ENGINE: USER AND ADMINISTRATOR MANUAL Version 3.0”, which has been produced as an addendum to the software deliverable D6.4 Platform Implementation and Integration - second prototype.

1 Introduction

The deliverable reflects the concrete work performed by the SmartH2O partners in analysing, designing, and implementing the incentive system for two very different pilots:

- The Swiss pilot: this is a small-scale pilot (around 400 households), which has been conceived as a test bed for the testing and fine-tuning of the incentive and SmartH2O gamification techniques. The small scale of the pilot permitted the deployment of a full-fledged spectrum of incentives, ranging from a basic version of the portal with only consumption display to a prize-based competition with real and valuable awards. Due to the limited scale, the experiment remained within the limits of the project budget, because the number of consumers expected to win a reward is affordable. However, the small numbers have permitted a deep functional and non-functional test of the many different technical features that support the delivery of incentives: user registration in multiple ways, action logging within the portal and in external applications,
- The Spanish pilot: this is a large-scale pilot, deployed to 400'000 customers. The scale of the pilot (much larger than the one originally foreseen in the project work plan) has challenged the definition of the incentive mechanism in many respects:
    - **Technical scalability**: the Gamification Engine must be able to cope with a large consumer base, which entails the logging and rewarding of a potentially very large set of internal and external actions.
    - **Budget constraints**: in a large-scale ***innovative*** pilot, where there is very little prior expertise on the achievable degree of engagement and participation of water consumers to the proposed activities, a competition-based approach to gamification with real world (and thus costly) rewards is potentially a challenge to the budget. Therefore, a realistic incentive system must be able to cap the budget investment in rewards, without jeopardizing the competition effect designed in the incentive system.
    - **Legal constraints**: a pilot deployed to the entire customer base is no longer a pilot, ***but is a real world application***; therefore, further constraints descend from the relationship between the (public) water utility company and its customers (the citizens). The most prominent constraint is the impossibility of performing classic A/B testing of the interface and stimuli at such a large scale, because equal and fair competition rules must be granted to all participants; this requirement forbids sending different versions of the portal to randomly selected user groups and comparing the response to such alternative versions. Indeed, a user could complain (also legally) for not having achieved an objective or won an award due to a reduced version of the gamified system he was exposed to. Therefore, the incentive evaluation methodology must be defined in such a way to be able find a scientifically sound way to assess the impact of different incentive stimuli, despite the fact that all citizens must "see the same interface".

At the same time, the incentive system for both pilots employs the same behavioral change model, which bases on the literature, but adapts to the specific SmartH2O application context. The description of the developed individual incentive elements is contextualized within the SmartH2O behavioral change model and they are systematically tested with different means (simulation, user survey, user-system interaction logging). In this way, the deliverable also exemplifies how incentive models and mechanisms for such behavioral change support systems for real-world applications can be designed in a systematic manner.

2 Survey of incentive models and theories

This section surveys the formal background of persuasive applications, which aim not only at performing a function, but also at inducing a (transient or permanent) change in the behaviour of users.

2.1 Motivation theory and its application to in SmartH2O

Incentivizing users to engage in water saving actions is of crucial importance to the success of the SmartH2O social awareness application, because water consumption behaviour is – like many other behaviours that have impact on the environment – mainly an habit-driven behaviour that occurs without active thinking (Dahlstrand and Biel, 1997). Users need to be motivated to expose themselves to water consumption information, to start thinking actively about their water consumption behaviour, and finally to engage in water saving actions.

This section therefore first outlines the main motivational theories, explaining the main drivers of human behaviour. Subsequently, we zoom in on one solution that has been employed in many different application areas to incentivize users, and which has also been adopted in SmartH2O: gamification, the use of game design elements in non-game contexts [Deterding, 2011]. Drawing on motivational theories we outline different gamification models and theories (section 2.3). The theories all postulate that the design process of gamified applications should take into account that different users have different motivations, and consequently that gamified applications should provide motivational affordances according to the composition of the target group.

In Section 3, we subsequently place the theoretical notions from this section in the specific context of the behavioural change we want to induce in SmartH2O: reducing water consumption by raising awareness and incentivizing users to engage in water saving actions. Section 2 and Section 3 are then the basis for the SmartH2O incentive model that is described in Section 4.

2.2 Psychological theories of motivation in relation to games

In this section, we examine the motivation theories in the context of games and gamified applications. Motivation theory has received a lot of attention in psychological literature, resulting in a variety of and disagreement about definitions of human motivation (e.g. [Kieinginna and Kieinginna, 1981]). Motivation may be defined as the energization (i.e., instigation) and direction of behaviour [Elliott and Covington, 2001, p. 73]. Motivation initiates, guides and maintains goal-oriented behaviour, what causes us to act [Cherry, 2013]. It represents the reasons for people's actions, desires, and needs.

Motivation concerns energy, direction, persistence and equifinality--all aspects of activation and intention. Although motivation is often treated as a singular construct, even superficial reflection suggests that 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 [Ryan and Deci, 2000b].

Research on gamification has been heavily influenced by the distinction between extrinsic and extrinsic motivation, which was introduced by Deci and Ryan [1985] in their self-determination theory. In self-determination Theory, the different types of motivation were distinguished based on the different reasons or goals that give rise to an action, between intrinsic motivation, which refers to doing something because it is inherently interesting or enjoyable, and extrinsic motivation, which refers to doing something because it leads to a separable outcome [Ryan and Deci, 2000a]. This distinction between intrinsic and extrinsic motivation has strongly influenced research and practice of gamification.

Intrinsic Motivation

Intrinsic motivation 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. This natural motivational tendency is a critical element in cognitive, social, and physical development because through acting on one's inherent interests is how one grows in knowledge and skills. 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 [Ryan and Deci, 2000a].

If we consider intrinsic motivation under the idea that all behaviours are motivated by rewards, then in intrinsically motivated activities the reward is in the activity itself. An intrinsically motivated person is moved to act by the fun or challenge entailed in an activity rather than by external prods, pressure, or rewards [Ryan and Deci, 2000a]. Intrinsic motivation, the inherent tendency to seek out novelty and challenges, to extend and exercise one's capacities, to explore, and to learn [Ryan and Deci, 2000b].

Extrinsic Motivation

Intrinsic motivation is not the only type of self-determined motivation [Deci and Ryan, 1985] and much of what people do is not, strictly speaking, intrinsically motivated, especially after early childhood when one's freedom to be intrinsically motivated is increasingly curtailed by social pressures to do activities that are not interesting and to undertake certain new responsibilities [Ryan and Deci, 2000b].

Extrinsic motivation relates to activities conducted for achieving specific outcomes (whether or not such an activity is also intrinsically motivated). Extrinsic motivation generally comes from the "outside". Common extrinsic motivations include rewards (e.g. money or grades) for showing a desired behaviour, and threats of punishment following misbehaviour. 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 [Bainbridge, 2013].

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 [Deci et al., 2001]. Pink [2011] argues that that some extrinsic motivators like money do not work well for creative and complex tasks. Instead, long-term social status rewards can be more effective for such tasks (ibid.). Using extrinsic motivation for controlling behaviour often creates negative feelings. In contrast, intrinsic motivation is often more meaningful to persons and results in a positive change of a person's mindset [Deci et al., 1999].

In the specific context of gamification research, Richter, Raban and Rafaeli [2015] following Vassileva [2012] presented a spectrum of motivational theories that range from extrinsic through social to intrinsic motivation (see Figure 1).

At the one extreme of this spectrum lies the extrinsic motivation, the focus of *Expectancy Value Theory* and *Skinner's Reinforcement Theory*, which explains the motivation to perform actions or present behaviours that induce extrinsic rewards [Vassileva, 2012]. 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) [Festinger, 1954]. Last, the Self-determination theory extends from the one end to the other as it encompasses both intrinsic and extrinsic motivation.

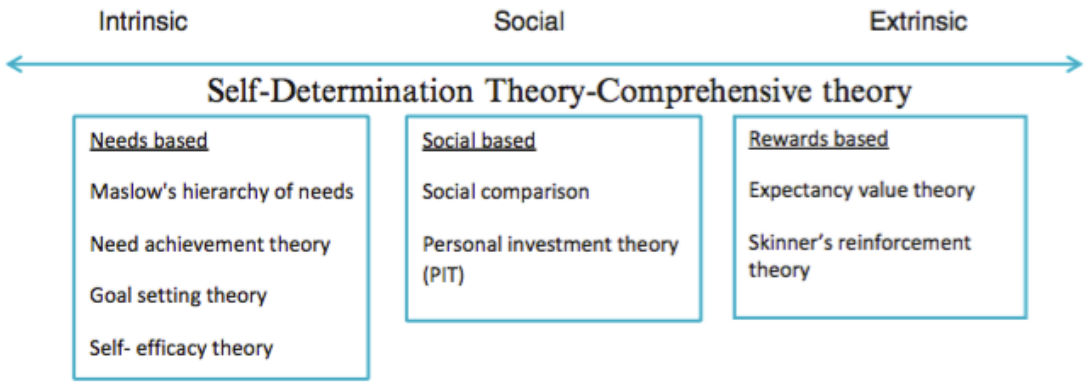


Figure 1. Model of motivation in games [Richter et al., 2015].

Below we review the different needs-based, social-based, and rewards-based motivational theories that are included in Figure 1. We highlight how these theories influence the design of gamified applications and the choice for particular game mechanics.

2.2.1 Needs-based motivation theories

Maslow's *Hierarchy of Needs* [Maslow, 1943] belongs to the earliest theories of motivation. It postulates that human behaviours are driven by the desire to satisfy physical and psychological needs. Maslow proposes a five-level scheme of needs, starting from physical needs and needs for safety and security and progressing to more complex needs such as desire for belongingness, self-esteem and self-actualization and one should satisfy the first levels before progressing to the complex ones, which are produced by positive incentives [Richter et al., 2015].

This theory became the basis for the effort to bring the theory in the (computer) games' context [Siang and Rao, 2003] and illustrate player needs (see Figure 2). It is contended that needs at the lower levels have to be fulfilled before moving to the higher levels in the pyramid. 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 [Siang and Rao, 2003]. 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 the *belongingness need* follows, 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-actualisation need*, players want to be able to do anything within the game rules and constraints [Siang and Rao, 2003; Richter et al., 2015].

According to the *Need Achievement Theory* [Atkinson, 1960], investigating the need for achievement, Achievement behaviour is directed at developing or demonstrating to self or to others high rather than low ability [Richter et al., 2015]. 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 tasks of intermediate difficulty but if the motive to avoid failure is stronger, people tend to prefer either very simple or very difficult tasks [Atkinson, 1960; Richter et al., 2015].

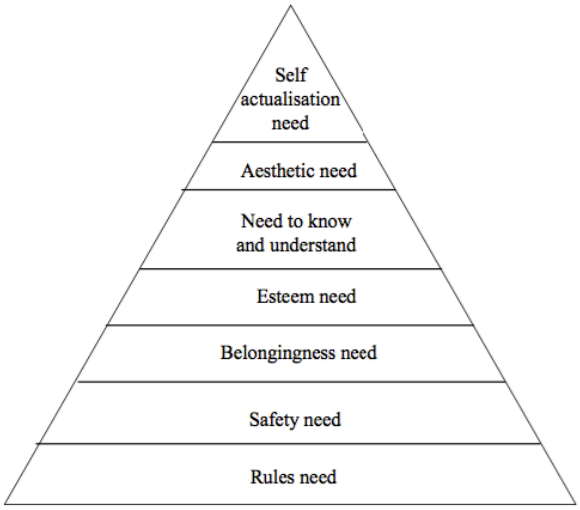


Figure 2. Hierarchy of the players' needs [Siang and Rao, 2003].

The need achievement 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 [Ling et al., 2005]. A goal is what the individual is trying to accomplish, the object or aim of an action and goals affect the performance by directing attention, assembling effort, increasing persistence and belief in ability to complete a task [Locke et al., 1981]. Goal efficiency is affected by three features: proximity, difficulty, and specificity. Good goal setting incorporates the SMART criteria, i.e. goals should be: specific, measurable, accurate, realistic, and timely. In many cases a goal should present a situation with a relatively short time span between the initiation of behaviour and the end state. A goal should be moderate, i.e. not too hard or too easy to complete. On one hand people look for challenges (implying some kind of insecurity of success). 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 classic example of a poorly specified goal is to achieve the highest possible grade in an educational context. Most children have no idea about the specific amount of effort required to reach that goal.

A game context usually defines a specific goal for a player. The goal-setting theory is based on the notion that individuals often strive to reach a clearly defined end state. Often, this end state is a reward in itself.

Self-efficacy theory [Bandura, 1977] focuses on the individual's belief in his/her 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 [Schwarzer et al., 1997; Richter et al., 2015].

While not included in [Richter et al., 2015] but strongly related to the needs-based theories, basic desires theory identifies sixteen basic desires that guide a large part of human behaviour [Reiss, 2002]. The sixteen basic desires have been identified from studies involving more than 6,000 people. These desires, which motivate our actions and define our personalities, are listed in Table 1.

Gamification has the potential to incentivize users by appealing to one or more of these basic human desires. For example, game play that involves competition appeals to the desire of vengeance, the use of leaderboards can give social status to users, or collecting points and badges can appeal to users' desire to save. The 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.

Table 1. 16 basic desires that motivate actions and define personalities [Reiss, 2002].

1.	Acceptance, the need for approval
2.	Curiosity, the need to learn
3.	Eating, the need for food
4.	Family, the need to raise children
5.	Honour, the need to be loyal to the traditional values of one's clan or ethnic group
6.	Idealism, the need for social justice
7.	Independence, the need for individuality
8.	Order, the need for organized, stable, predictable environments
9.	Physical activity, the need for exercise
10.	Power, the need for influence of will
11.	Romance, the need for sex and for beauty
12.	Saving, the need to collect
13.	Social contact, the need for friends (peer relationships)
14.	Social status, the need for social standing and importance
15.	Tranquillity, the need to be safe
16.	Vengeance, the need to strike back and to compete

2.2.2 Social-based motivation theories

The social aspect is also significant in games [Ling et al., 2015] and this has been particular obvious in gaming applications integrated in social networks like Facebook, which offer a setting for socialization in a playful manner, attracting huge popularity [Richter et al., 2015].

Social Comparison Theory and Personal Investment Theory elaborate the social side of games [Richter et al., 2015]. The Social Comparison Theory [Festinger, 1954] is based on the idea that people tend to compare themselves with others, who they consider as similar to them, in order to evaluate or enhance some of their personal aspects, such as their beliefs and abilities [Vassileva, 2012; Richter et al., 2015].

The Social Comparison Theory 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 [Vassileva, 2012]. Furthermore, Vassileva [2012] noted that comparison- or reputation-based mechanisms increased the contribution from the users in several systems and claimed that social comparison can be a powerful incentive to effectively increase contributions to online communities.

The Personal Investment Theory [Schilling and Hayashi, 2001] 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 [Richter et al., 2015]. It integrates social influences with the examination of achievement motivation. The theory defines three basic components of critical meaning to determining personal investment in specific situations: personal incentives, sense of self and perceived options [Schilling and Hayashi, 2001; Richter et al., 2015]. The personal incentives can be intrinsic or extrinsic and 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 (e.g. monetary compensation or social recognition and approval from important persons). 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 alternative choices, available and appropriate and often influenced by social aspects [Richter et al., 2015].

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 [Richter et al., 2015], Vassileva [2012] include the Expectancy Value Theory and the Reinforcement theory.

Eccles et al. [1983] proposed an expectancy–value model of achievement performance and choice [Wigfield and Eccles, 2000]. *Expectancy value theory* relates to the strength of motivation to strive for a certain goal, to the expectations to attain the desired goal, and to the incentive value of that particular goal [Richter et al., 2015].

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 [Wigfield and Eccles, 2000].

Eccles et al. [1983] defined different components of achievement values: *attainment value or importance*, *intrinsic value*, *utility value* or usefulness of the task, and *cost*. Attainment value was 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. Utility value or usefulness refers to how a task fits into an individual's future plans (e.g. taking a math class to fulfil a requirement for a science degree). Last, the 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. [Wigfield and Eccles, 2000].

As pointed in [Wigfield and Eccles, 2000], interest value is a construct similar to the construct of intrinsic motivation as defined by Deci and Ryan [1985] because it concerns doing a task out of interest and enjoyment. Similarly, utility value captures more ''extrinsic'' reasons for engaging in a task, 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.

The *Reinforcement Theory* was proposed by Skinner [1957], stating that individual's behaviour 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. Skinner noted that continuous reinforcement establishes desired behaviours quicker than partial reinforcement. However, once the continuous reinforcement is removed, the desired behaviours extinguish fast [Richter et al., 2015]. Skinner's Reinforcement Theory explains the motivation to perform actions or behaviours that lead to extrinsic rewards.

2.2.4 Self-Determination Theory

Self-Determination Theory (SDT) represents a broad framework for the study of human motivation and personality, articulating a meta-theory for framing motivational studies, a formal theory that defines intrinsic and varied 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 [Self-Determination Theory, 2016]. Thus the Self-Determination Theory focuses on types of motivation and proposes that motivation is multidimensional and resides along a continuum of self-determination ranging from intrinsic motivation, through extrinsic motivation to a motivation [Richter et al., 2015], the state of lacking the intention to act.

Intrinsically motivated behaviours are performed out of interest and satisfy the inherent psychological needs for competence and autonomy are the prototype of self-determined behaviour. Extrinsically motivated behaviours—those that are executed because they are instrumental to some separable consequence—can vary in the extent to which they represent self-determination [Ryan and Deci, 2000a]. Thus, extrinsic motivation refers to performing a

task in order to attain some separable outcome while intrinsic motivation, refers to performing an activity for the inherent satisfaction of the activity itself (see also section 2.2).

SDT discusses three psychological needs: autonomy, competence, and relatedness. Autonomy is the ownership of one's behaviour, the ability to make choices according to own free will. Competence is 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 autonomy, competence, and relatedness are argued to foster the most volitional and high quality forms of motivation and engagement for activities, including enhanced performance, persistence, and creativity [Self-Determination Theory, 2016]. In contrary, when these needs thwarted, this lead to diminished motivation and well-being [Ryan and Deci, 2000b]. In addition, SDT 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 [Self-Determination Theory, 2016].

2.2.5 Motivation theories and game design

There are a multitude of games that drew people's attention over time. They have different structures and are based on diverse concepts, but they can all be represented by three underlying dimensions [Hunicke et al., 2004]:

- **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, behaviours 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 (see Table 1 for a connection between game mechanics and human desire);
- **Aesthetics**: the overall experience — response evoked within the player when the player interacts with the game, like pride, envy, surprise, connection, satisfaction, fun, etc.

In Richter et al. [2015] game mechanics are attempted to be explained based on the aforementioned motivation theories and mapped correspondingly. It is pointed out, for example, that the social comparison theory and the tendency of people to compare themselves with others, can explain the motivational effect of the leaderboard. Similarly, badges can be one's achievement advertisement as well as a goal-setting device. Table 2 is based on this mapping in Richter et al. [2015].

Table 2. Motivation theories and game mechanics [Richter et al., 2015].

Game Mechanics/Incentives	Motivation Theory(-ies)
Progress bar	Self-efficacy, Basic desires
Special effect (audio, visual etc.)	
Points/bonus	Self-efficacy, Goal-setting, PIT, Expectancy Value, Need Achievement, Basic desires
Mini games/challenges/quests	
Badges	Self-efficacy, Goal-setting, PIT, Expectancy Value, Social Comparison, Basic desires
Leaderboard	
Achievements	Self-efficacy, Goal-setting, PIT, Expectancy Value, Need Achievement, Social Comparison, Basic desires
Levels	
Avatar	Social Comparison, Personal Investment Theory (PIT), Expectancy Value, Basic desires

The table underlines the potential of games to relate to intrinsic, extrinsic, and social motivations. 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 [Richter et al., 2015]. In line with social comparison theory, social motivations are triggered by providing social recognition and status in the player community through levels, badges, and leaderbords.

The table demonstrates that the most common game mechanics are in line with basic desires theory. 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. In SmartH2O we have adopted a user-centred design process [Norman, 1988] to ensure that the user's needs and goals are the primary consideration at every stage of – in this case – a game design process. Applications of user-centred design principles are necessary to avoid meaningless, or even harmful, gamification. Scott Nicholson et al. [2012] claim that dependence upon extrinsic rewards for motivation should be replaced by connections between the non-game activity and needs or goals in the user's life. The resulting user-centred gamification is expected to result in longer-term and deeper engagement between participants in non-game activities and supporting organizations.

As a first step towards a gamified incentive model that is differentiated by user motivations, we discuss different theoretical models on gamification that address player types, gameplay environment, emotional responses to gameplay, and the relationship between motivation and ability in games. The models help to understand how game designers can make people want to play and persist in their play, given the differences in motivation between players.

2.3.1 Bartle's Player Categorization

Different players have various desires in games and their important factors of the game are also different. Therefore, in order to create the right motivation for people to play game, we should understand the characteristics of various players. In Hearts, Clubs, Diamonds, Spades: Players Who Suit Muds, Bartle [1996] categorizes players into four roles which are: **Achievers**, **Explorers**, **Socializers** and **Killers**.

- **Achievers** are 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** 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. They know all the mechanics, short-cuts, tricks, and glitches that exist in the game and work hard on discovering more;
- **Socializers** 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 role-playing);
- **Killers** prefer to provoke and cause drama and impose them over other players according to game's possibilities.

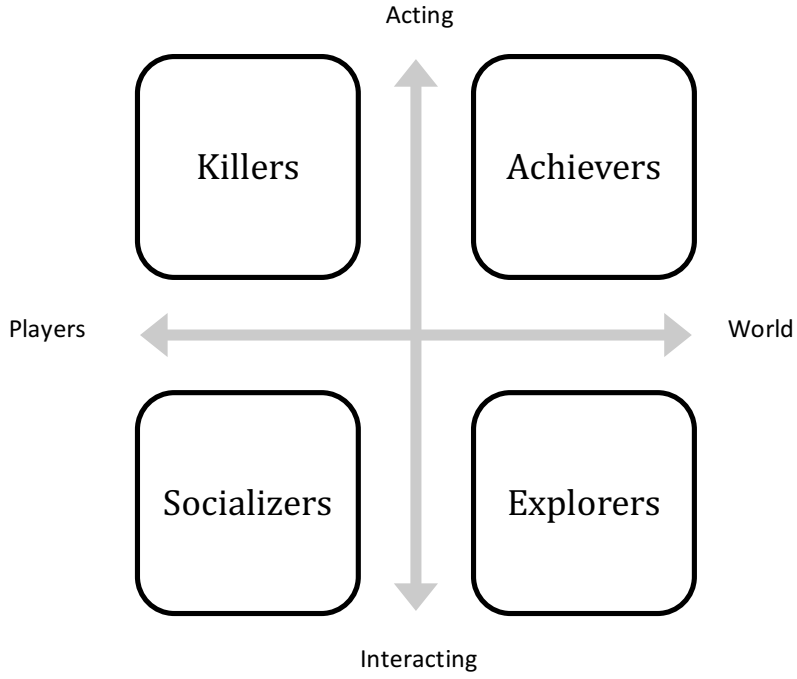


Figure 3. Bartle's player categorization.

There are some players can have characteristics of all four types at the same time. However, most of them are not. On average, the distribution looks like this:

- 80% socializers
- 50% explorers
- 40% achievers
- 20% killers

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

From the Bartle framework 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 [Kim, 2012]. Inspired by Bartle work, Amy Jo Kim 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 [Bartle, 1996]: **Compete**, **Collaborate**, **Explore**, and **Express** (Figure 4).

According to Kim [2012], achievers are players who like to compete. However, it's just one of many motivators — and often not the best. Socializers, on the other hand, prefer collaborate to compete. Kim states that from Facebook "likes" to Kickstarter projects, 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 [Kim, 2012]. Explorers are interested in exploring content, people, and tools. People who enjoy exploring are motivated by information, access and knowledge; stand-alone points will be meaningless to them. This type of players is potential for word-game and knowledge based system liking what we are developing. For killers, Kim states that self-expression is a key driver for modern social gaming and social media, and also is a major motivator for engagement and purchases. People who enjoy self-expression are motivated by greater abilities to showcase their creativity and express who they are [Kim, 2012]. Figure 5 shows more actions relating to her point of view.

Figure 4. Ami Jo Kim's view on Bartle's model.

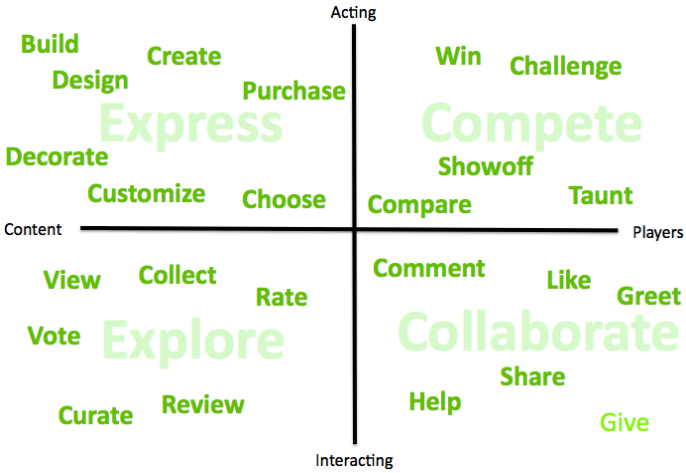


Figure 5. Ami Jo Kim's Social Engagement Verbs.

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 6 [Radoff, 2011]. The horizontal axis describes the number of players involved in an element of gameplay. The further to the left you go the closer to a single player; the more to the right, the more players. The vertical axis represents the measurement used to communicate to players whether they are 'winning' in the category of motivation: as you go upwards, things go from very 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.

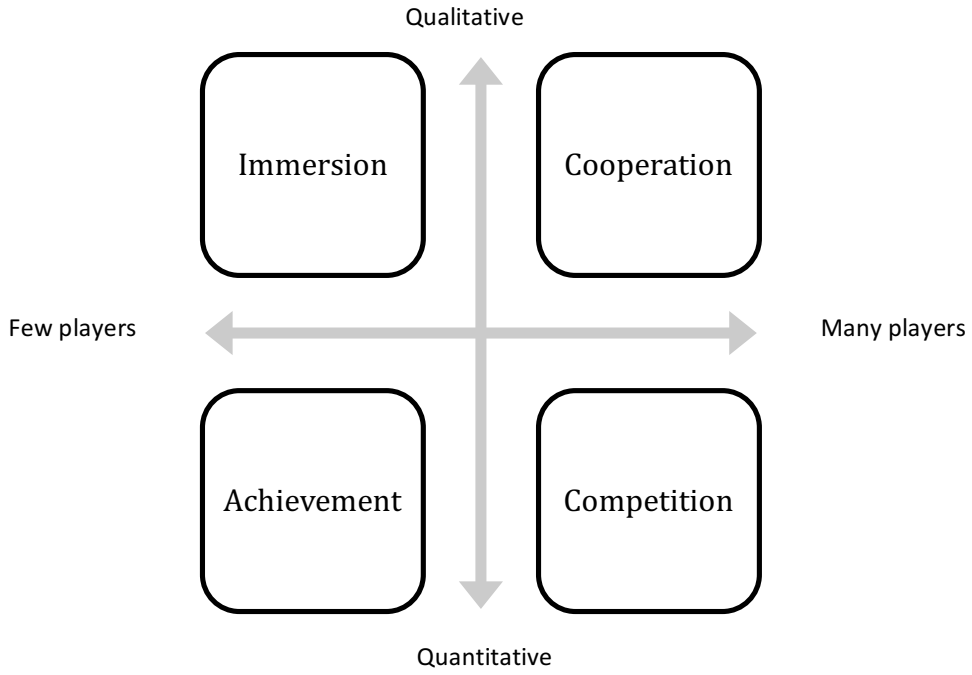


Figure 6. Radoff's gameplay model.

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 [Lazzaro, 2004]:

- **Hard Fun**: Emotions from Meaningful Challenges, Strategies, and Puzzles" [Lazzaro, 2004]. 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. The game needs to have feedback on progress and success of players to inspire their creativity of strategies. We also need to balance game difficulty with player skill through levels.
- **Easy Fun** grabs attention with ambiguity, incompleteness, and detail" [Lazzaro, 2004]. 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, behaviour, and other people" [Lazzaro, 2004]. 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" [Lazzaro, 2004]. 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. According to Nicole Lazzaro's point of view, 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 Behaviour 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 Behaviour (FBM) [Fogg, 2009], a behaviour model (see Figure 7).

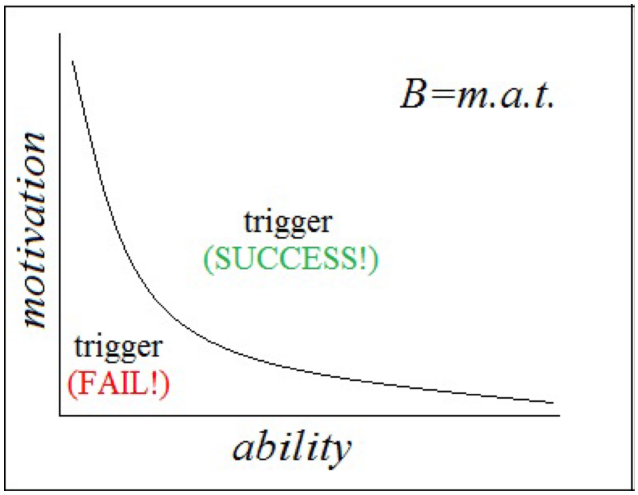


Figure 7. The Fogg Behaviour Model [Fogg, 2009].

B. J. Fogg says there are three factors underlying any human behaviour: motivation, ability and triggers. For the behaviour 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 behaviour. On the other hand, a person situated on the left side of the horizontal axis will have low ability to reach a target behaviour. So, as a person has increased motivation and increased ability, he or she will be more likely to perform the target behaviour. 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 behaviour: from an alarm that sounds or a text message to an advertisement.

3 The SmartH2O Behavioural Change Approach

In SmartH2O, a systematic approach is followed to induce sustainable change in water consumption behaviour that is grounded in motivational theory and research on incentive models. In order to maximize the effectiveness of the social awareness application, a broader outlook on the behavioural change process is needed, which also consider the steps necessary after incentivizing users to retain their attention and engagement. For that reason, the application needs to be perceived as a behavioural change support system (BCSS): "a socio-technical information system with psychological and behavioural outcomes designed to form, alter or reinforce attitudes, behaviours or an act of complying without using coercion or deception" [Oinas-Kukkonen, 2013, p. 1225]. In line with this definition, the SmartH2O social awareness approach is based on the assumption that a change in water consumption behaviour only occurs when underlying psychological determinants are changed through a combination of different incentive and persuasion strategies. The definition also raises the question of *how* these determinants and ultimately water consumption can be changed. In this section we first address the determinants, followed by the behavioural change process (e.g. the 'how'), and finally outline the development approach for the SmartH2O social awareness app, as the implementation of the SmartH2O behavioural change strategy.

3.1 Determinants of water consumption

Research has shown that water consumption behaviour 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'.

For the analysis of the psychological determinants, we draw on a renowned model from behavioural psychology. Ajzen [1991] has introduced and validated the Theory of Planned Behaviour (TPB), as the successor of the Theory of Reasoned action [Fishbein and Ajzen, 1975]. TPB models the relationship between attitudes, intention, and the target behaviour (i.e. water consumption). As such, it incorporates the constructs that have been introduced in the Expectancy-Value theory (see Section 2.2.3). The TPB-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 8.

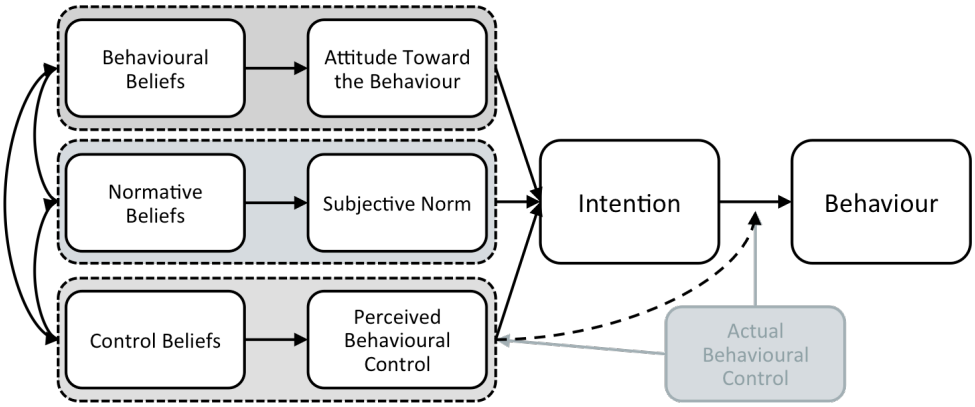


Figure 8. Theory of Planned Behaviour [Ajzen 2006].

The core constructs of the TPB model are:

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

Whereas this model has been applied in many different settings, one of its main criticism is that it cannot adequately explain habitual behaviours. Habits are automatic behavioural tendencies that arise as a result of repetition and practice of actions in similar situations [Ouellette and Wood, 1998]. Habits become stronger when the frequency with which the behaviour is performed increases (ibid.). 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.

Secondly, whereas the TPB model explains behaviour based on the *specific* beliefs and attitudes towards the targeted behaviour (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 more *general* beliefs and attitudes towards the environment impact behaviour [Corral-Verdugo et al., 2002 Willis et al., 2011; Bamberg, 2013].

Additionally, the hedonic values of an individual (related to comfort levels and feelings) have shown to negatively affect both environmental attitudes and environmental behaviours [Steg et al., 2014]. Therefore, a successful behavioural 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.

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

In the context of water consumption behaviour, different attempts have been made at developing a more comprehensive model. Jorgensen et al. [2009] have reviewed social and econometric models. Their review pointed out that existing models suffer from low explained statistical variances and that a new model is needed that comprehensively covers psychological, social, and economic factors. Their new integrated model combines these factors, with the TPB model at its core. The model elaborates the attitude concept to include specific attitudes towards water consumption restrictions, water pricing, and water conservation, while incorporating acknowledging the habitual nature of water consumption. Finally, socioeconomic, demographic characteristics, and climate/seasonal factors are introduced as drivers of water consumption.

However, in this model – 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. In contrast, in SmartH2O, the continuous (gamified) incentivization of users throughout the behavioural change process is at the centre of our attention, as has been explained in the previous section.

Finally, it should be noted that this model offers a *static view* on behavioural change. In the next subsection we propose an alternative perspective, stating that the behavioural change process in SmartH2O should be considered as a *multistage process*.

3.2 A multistage approach to induce sustainable changes in water consumption

Whereas earlier attempts at changing water consumption behaviour have relied on information campaigns distributed via mass media, the advent of smart meters enables the provision of detailed individual consumption feedback. Recent studies present both design cases and experiments that exploit this new opportunity. For example, Fielding et al. [2013] have conducted a field experiment in which the effect of smart meter-enabled water consumption feedback interventions and social norm-based interventions have been compared. They found that effects dissipate over time, with water consumption levels returning to almost pre-treatment levels after twelve months (ibid.).

This dissipating effect highlights a key problem in both experimental research and design studies: the same message is sent to all users, regardless of their beliefs, attitudes, or behaviour. Developed within the health domain, the trans-theoretical model for behavioural change [Prochaska and DiClemente, 1986; 1992; Prochaska et al., 2008] rejects this 'one taste fits all' approach. Prochaska and DiClemente, 1986; 1992; Prochaska et al., 2008) argue that people change their behaviour by progressing through five consecutive phases that range from raising awareness ('precontemplation') to eventually creating new habits by drawing on intrinsic motivations.

Whereas in the health domain there is much evidence that provides empirical support for the existence of these phases, in the domain of environmental psychology in general, and water saving in particular, few attempts have been made to apply and validate the model in this context. As an exception, Ai He et al. [2010] have defined specific motivational goals for each of the phases in the context of sustainable energy, and provided design recommendations for systems that target the needs of users in each of the phases. Additionally, a few design cases in the water consumption domain have been reported that apply the principles of the transtheoretical model (e.g. Arroyo et al., 2005).

SmartH2O contributes to the body of knowledge of behavioural change in water consumption by applying this model to said domain, and by reshaping the phases to match the cognitive and motivational processes involved in water consumption. First, we should acknowledge that the behavioural change process is not completely linear, as users can and will relapse to earlier phases. Second, we reject the assumption of clear-cut boundaries between stages, which has also been criticized in the health domain (e.g. [West, 2005]). Rather, following Noël [1999], we postulate that users progress gradually from one stage to the other, with cognitive and behavioural processes of change following an inverted-U-shaped pattern of variation as they move toward effective change: each process is first increasingly used, up to a maximum value, and then decreases. Finally, the pre-action phase and action phase are merged, arguing that the promoted change of behaviour is relatively small, and requires – in contrast to the addictive behaviours for which the model was originally developed – too little planning to justify a separate phase in the process. In Table 3 the final four phases are described, and their motivational goals are listed.

Note that even though the names for the phases were adopted from the trans-theoretical model, in the context of water saving they should be treated as a figure of speech. That is, whereas in the contemplation phase, active cognitive processing can be expected to some level, 'contemplation' suggests that users extensively think about water with their full attention during longer intervals. Rather, we expect users to rethink their beliefs and attitudes with low to moderate cognitive effort over the course of time after exposure to water-related information or incentives.

In SmartH2O, the multistage model has been the basis for the design and development of a BCSS that offers a range of incentives and arguments, providing support to users throughout the full behavioural change process. This approach builds on findings from experimental research that demonstrate that information alone is incapable of inducing significant and sustainable behavioural change in water consumption (e.g. Schulz et al., 2014; Fielding et al., 2013). Rather, it requires a combination of different strategies and incentives. In the following

sub sections we outline possible strategies for each of the phases in the behavioural change process.

Table 3. Phases in the behavioural change process.

Phase	Behavioural change state	Motivational goal
Pre-contemplation	People are unaware of the need for behavioural change, and have no intention to change their behaviour in the next 6 months. People overestimate the disadvantages of the behaviour, and underestimate the advantages.	• "Plant the seed" to acknowledge problematic water consumption behaviour
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 behaviour.	• "Tip the balance in favour 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 behaviour more than six months ago, they need to gain awareness of situations that may tempt them to slip back to the old behaviour.	• Maintain durable behaviour change in water consumption • Develop intrinsic motivations for saving water

3.2.1 Precontemplation: plant the seed

The first step towards water saving is to raise awareness about problematic behaviour: users consuming too much water. The SmartH2O system needs to employ different strategies to help users overcome the following hurdles that prevent them from saving water:

- The **habitual nature** of water consumption
  As with many other environment-related behaviours, habits have a strong influence on water consumption behaviour [Jorgensen et al., 2009; Fielding et al., 2012]. As a first step in the behavioural change process, the unsustainable water consumption behaviour needs to be "unfrozen" [Dahlstrand and Biel, 1997]. Thus, users need to be incentivized and their awareness about water consumption needs to be raised. Appealing to the user's general needs and desires, as outlined in Section 2, is an important part of the pre-contemplation phase that can help to bring water consumption behaviour to their explicit attention.

- **Unclear consequences**
  Furthermore, the disadvantages of consuming more water than needed are not immediately visible to the user, which according to Schwarzer's [1997] norm activation model for environmental behaviour is likely to hinder behavioural change.

This model explains an individual's environmental behaviour as a result of personal norms, perceived outcome efficacy, and awareness of consequences [Steg and Vlek, 2009]. In the precontemplation phase, it is then important to make users more aware of the consequences of their behaviour, and demonstrate what they can do by themselves to change or avoid the negative consequences.

- **Balancing goals**
  Goal framing theory [Lindenberg and Steg, 2007] suggests that for an individual user, three types of goals are active at the same time: hedonic goals, gain goals, and normative goals. Hedonic goals lead individuals to focus on ways to improve their feelings in a particular situation, such as avoiding effort, seeking direct pleasure or seeking excitement. Gain goals prompt people particularly to be 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 [Steg et al., 2014, p. 104]. Individuals process information based on the goal that is most in focus in the current context. Lindenberg and Steg [2007] argue that pro-environmental behaviour can be promoted by strengthening normative goals or by making gain and hedonic goals less incompatible with normative goals.

- **Unclear social norms**
  In different contexts, including energy saving, activation of social norms has been suggested as an effective strategy for the pre-contemplation phase (e.g. [Ai He, 2010]). A distinction needs to be made between two types of social norms. Descriptive norms refer to an individual's beliefs about the prevalence of certain behaviour 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 behaviour [Schulz et al., 2014, p. 3]. Social norm-based feedback should ideally combine both types of norms into a single message, as experimental research has shown that the condition with a combined message outperforms the two conditions with a separate descriptive and conjunctive message [Schulz et al., 2014].

3.2.2 Contemplation: tip the balance in favour of water saving

In the contemplation phase, users actively think about their water consumption behaviour. Strategies should be aimed at tipping the balance towards favourable attitudes on saving water.

Interventions in this phase should target the user's lack of specific factual knowledge about how much water they consume (aggregated, and on the level of specific appliances), as these behavioural beliefs are according to the TPB model the best predictors for the user's attitude.

Additionally, people might question what they can actually do to save water. In a survey study carried out in Sydney, 31% of the respondents reported that they could do nothing more to save water [Randolph and Troy, 2008]. The authors also concluded 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 favourable attitudes on water consumption.

From the perspective of goal framing theory [Lindenberg and Steg, 2007], it is also important in this phase 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).

3.2.3 Action: reinforce positive behaviour

In this phase, users start putting the target behaviour into practice. In this phase, information on how users can change their water consumption behaviour needs to be provided. Whereas in the contemplation phase providing water saving tips is aimed at influencing the attitude

towards water saving, in this case water saving tips are directly aimed at supporting users in their new behaviour. Experimental research (e.g. [Fielding et al., 2013]) has shown that this is an effective approach: information that shows users how to save water indeed proved to lead to lower levels of water consumption in the first year after exposure to this information. This result is in line with self-efficacy theory (see Section 2.2.1).

In this phase, when the user is performing the intended behaviour, positive reinforcements are also needed as they help to keep the user engaged and to avoid setbacks, in terms of attitudes and behavioural intentions. In line with Skinner's classical work on conditioning and reinforcements, this phase requires positive reinforcements to secure the acquired behaviour as a new habit, provided that the user has been incentivized to question the old behaviour and to reflect on its negative consequences [Dahlstrand and Biel, 1997].

The BCSS should also strengthen the commitment users have towards the new water saving behaviour. Social sharing of positive outcomes, and setting goals in a way that is visible to significant others could increase commitment.

3.2.4 Monitoring: Develop intrinsic motivation and reinforce sustainable water consumption

A sustainable change in behaviour only occurs when users are intrinsically motivated to save water. That is, according to self-determination theory people will be motivated to save water when it contributes to their perceived level of competence, their psychological relatedness to others, or their sense of autonomy [Ryan and Deci, 2000a], as opposed to extrinsic motivation, such as (monetary) rewards. This phase should therefore be focused on internalizing the new behaviour, so that it becomes part of the individual's self. Ai He et al. [2010] recommend maintaining the cyclical loop of intrinsic motivation: interest, curiosity, optimal challenge, competence feedback and enjoyment. The importance of reinforcement is shown by longitudinal experimental research, which shows that without reinforcement, positive effects on water consumption dissipate over time (e.g. [Fielding et al., 2013; Stewart et al., 2013]).

3.3 From theoretical foundation to actionable strategies

In this section we have provided the theoretical foundation for the multistage behavioural change strategy the SmartH2O project adopts to engage users, and subsequently to change their water consumption behaviour.

Based on insights from environmental psychology and experimental research on water consumption behaviour, strategies were described that have been found in existing research to influence determinants of water consumption. Several problems have been found in current research: the habitual nature of water consumption, the well-known attitude-behaviour gap, and the dissipation of positive effects over time.

We have introduced two novel perspectives to overcome these problems. First, in SmartH2O we look at behavioural change as a multistage process, with different phases requiring different strategies. The SmartH2O social awareness app, as a behavioural change support system, offers incentives and feedback to users in all phases of the behavioural change process. Second, based on the review of motivational theories and gamification models in Section 2 we have positioned gamification as a solution to initiate and sustain the behavioural change process.

The analysis of motivational theories, the modelling of the behavioural change theories, and the positioning of gamification within the behavioural change process together provide the foundation for the definition of the SmartH2O incentive model, which is described in the next section.

4 Selection and implementation of incentive models and algorithms in SmartH2O

This section first outlines the conceptual design of the SmartH2O incentive model before documenting the specific algorithms and rules that have been employed in the SmartH2O social awareness application, as well as in the 'Drop! The Question' mobile game.

4.1 Conceptual design of the SmartH2Oincentive model

This section outlines the incentive model and structural framework of the SmartH2O social awareness app. The model is based on the behavioural change process analysis presented in Section 3 and the motivational theory inventory presented in Section 2, and draws on the user requirements elicitation results that were reported in D2.2. An overview of the process is depicted in Figure 9.

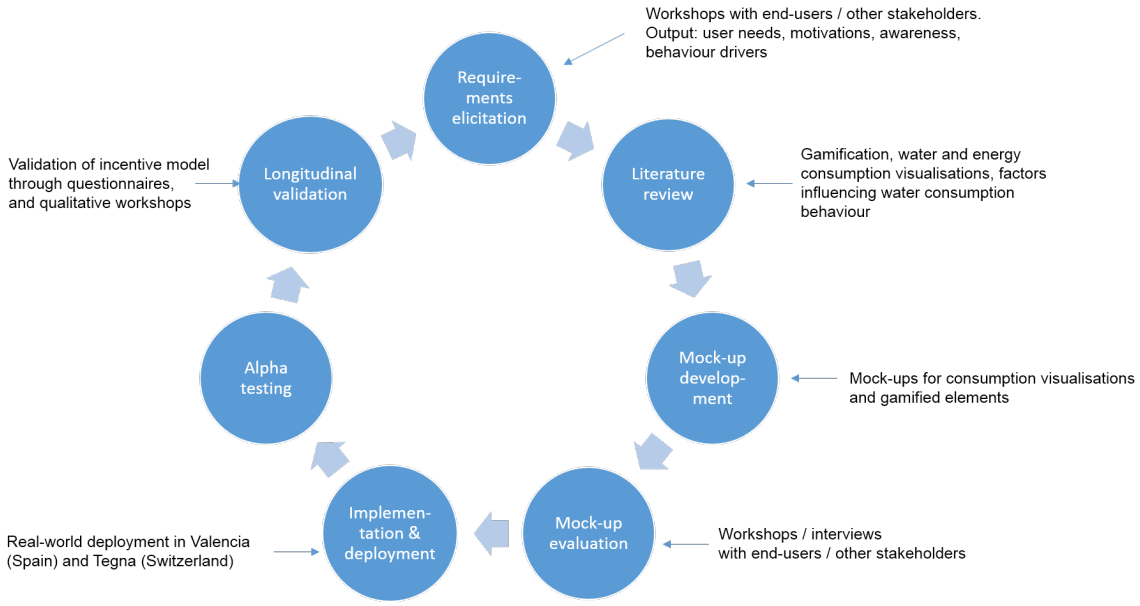


Figure 9. Gamification process.

The user requirements elicitation has produced a profound insight into user needs, motivations, water awareness, and facilitating conditions that need to be fulfilled in order to make the SmartH2O social awareness application successful. It has yielded four factors that need to be taken into account, which simultaneously constitute dimensions on which users differ from each other:

- Technology affinity: the digital skills and personal innovativeness of users [Lu et al., 2005].
- Data affinity: the perceived usefulness of detailed water consumption data.
- Environmental concerns: the extent to which users are concerned with environmental issues.
- Playfulness: the extent to which users want to engage in playful interactions with the system.

Additionally, the review of motivational theories and gamification models has demonstrated that users differ in terms of the motivational affordances they are sensitive to. These differences between users impose challenges on the design of the incentive model, requiring

a model that can engage *all* users regardless of their position on each of the aforementioned dimensions, or the motivational affordances that can engage them.

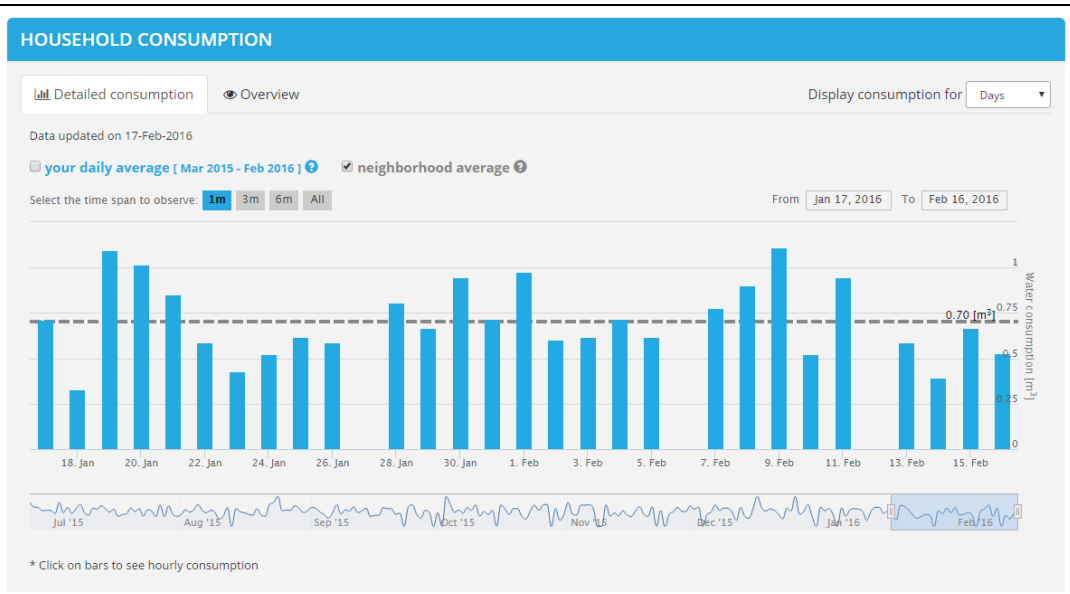
The SmartH2O social awareness app has been conceptualized iteratively to provide support for all phases in the behavioural change process, and to meet the needs of aforementioned classes of users through a process of mock-up development, workshop-based collection of end-user feedback, and formative evaluation (alpha testing).

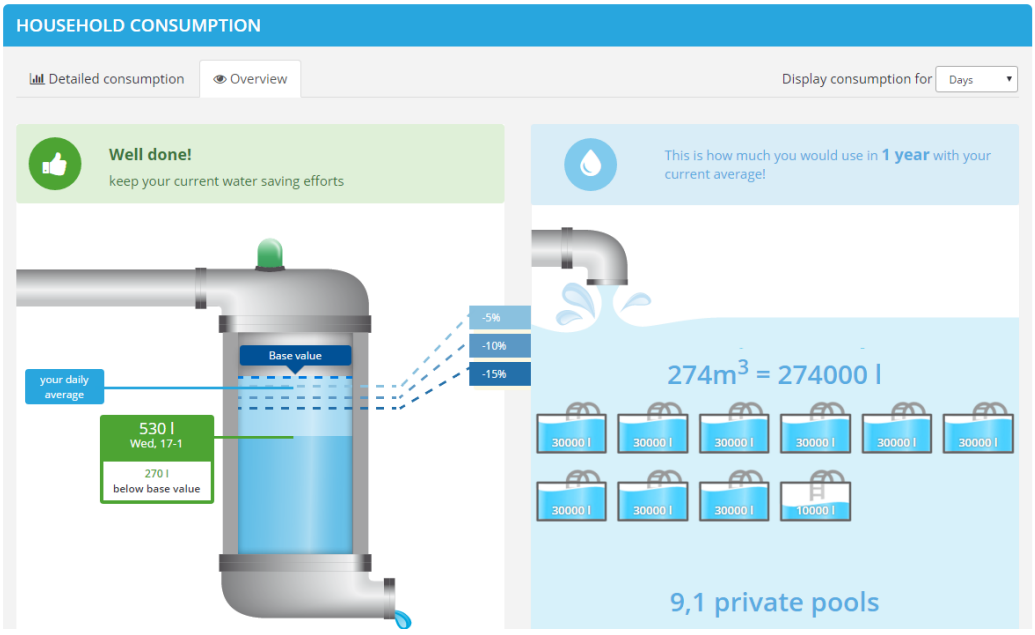
In terms of De Young [2000], the resulting incentive model employs both antecedent and consequence strategies. Antecedent strategies refer to strategies that influence the determinants of behaviour *before* the behaviour occurs, for example by seeking a commitment to water saving, setting goals, or providing information. On the other hand, consequence strategies are said to change behaviour by influencing determinants *after* the user enacts the behaviour. In this way, consequences (positive or negative) are linked to the outcome of the behaviour [De Young, 2000; Russell and Fielding, 2010]. The resulting functionalities can be grouped as follows:

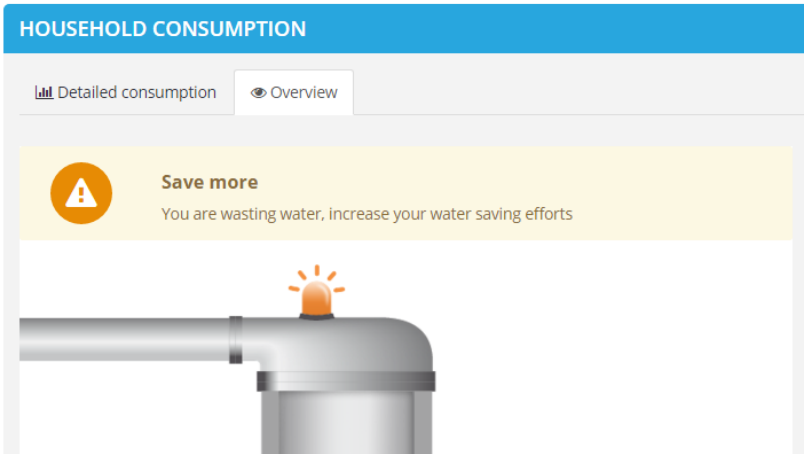
- Interactive exploration of water consumption data
- Incentives through physical, social and gamified virtual rewards
- Setting water consumption goals
- Competing against others
- Rewarding performance with points and badges
- Actionable water saving tips

4.1.1 Interactive exploration of water consumption data

Behavioural change phases	Precontemplation, Contemplation, Action, Monitoring
Class of users	*Affinity w/ technology:* high affinity *Affinity w/ data:* high playfulness *Environmental concerns:* all levels of environmental concern *Playfulness:* all users
Description	
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 neighbourhood. Users can display their water consumption over different timespans, with pre-defined options for 1 month, 3 months, 6 months, and the whole period during which consumption is measured. Additionally, bars can be displayed to represent a day, a week, or a month. On the second tab, a visualisation 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 are encouraged to engage in water saving by displaying water saving levels of 5%, 10% and 15% respectively. This second tab also displays the user's water consumption metaphorically and extrapolated over one year ("this is how much water you would use in one year"), in terms of private swimming pools filled with water, to make the amount of water spent tangible and significant. When consumption is decreased im comparison to the historical base value, a light on top of the pipe flashes green and a positive reinforcement message is displayed. In contrast, when consumption is increasing, a motivating warning message is displayed.	


HOUSEHOLD CONSUMPTION
Detailed consumption
Overview
Display consumption for
Days
Data updated on 17-Feb-2016
your daily average [Mar 2015 - Feb 2016]
neighborhood average
Select the time span to observe:
1m
3m
6m
All
From
Jan 17, 2016
To
Feb 16, 2016
0.70 [m³]
Water consumption [m³]
18. Jan
20. Jan
22. Jan
24. Jan
26. Jan
28. Jan
30. Jan
1. Feb
3. Feb
5. Feb
7. Feb
9. Feb
11. Feb
13. Feb
15. Feb
Jul '15
Aug '15
Sep '15
Oct '15
Nov '15
Dec '15
Jan '16
Feb '16
* Click on bars to see hourly consumption


HOUSEHOLD CONSUMPTION
Detailed consumption
Overview
Display consumption for
Days
Well done!
keep your current water saving efforts
This is how much you would use in 1 year with your current average!
Base value
your daily average
530 l
Wed, 17-1
270 l
below base value
-5%
-10%
-15%
274m³ = 274000 l
30000 l
10000 l
9,1 private pools


HOUSEHOLD CONSUMPTION
Detailed consumption
Overview
Save more
You are wasting water, increase your water saving efforts

Rationale
Experimental research [Fielding et al., 2012] has demonstrated that insight into actual consumption results in lower levels of water consumption, even though the sustainability of the achieved effects is problematic. Additionally, research in environmental psychology suggests that feedback can influence the underlying beliefs and attitudes towards water saving (e.g. [Steg et al., 2014]). Research in the area of energy consumption also points out the positive effects of displaying energy use levels (e.g. [Abrahamse et al., 2007]), albeit in combination with other interventions. Research suggests that user interface design influences hedonic quality, which is in turn linked to both engagement and task performance [Novak and Schmidt, 2009; Melenhorst et al., 2014; Hassenzal, 2004]. For the SmartH2O Social awareness app, water consumption charts are part of the behavioural change incentive strategy. Effort has been put into the visual appeal of the water consumption charts. It appeals to the user's need for achievement (need achievement theory, Atkinson [1960], see 2.2.1) in the sense that a well-visualized decrease of water consumption levels feeds the user's feeling of accomplishment, as well as the user's feeling of autonomy (self-determination theory, [Deci and Ryan, 1985]). The SmartH2O portal builds on users' normative goals of the desire to act appropriately [Lindenberg and Steg, 2007] by allowing them to compare their water consumption against both the neighbourhood average. Note that the neighbourhood average is particularly effective when the user consumes more than the neighbourhood average, but is less effective or even counterproductive when the user consumes less than the average. Therefore, by default this option is switched off. In the pre-contemplation phase, it is also suggested to raise awareness about the negative consequences of the current behaviour [Prochaska, 1992; Ai He, 2001]. The water consumption visualization incorporates this notion by displaying the user's water consumption as a number of swimming pools filled with water. Also, an injunctive normative message is given by means of the green or red light on top of the water pipe. The green and red light both highlight the behaviour that is expected from the user, and remind people of their past water behaviour. Van der Werff et al. [2014] have shown that reminding people of their past pro-environmental actions can be an effective approach, particularly when these actions strongly signal that one is a pro-environmental person.

4.1.2 Reinforcements through gamified virtual and physical rewards

Behavioural change phases	Precontemplation, contemplation, action, monitoring
Class of users	*Affinity w/ technology:* low affinity and higher *Affinity w/ data:* low affinity and higher *Environmental concerns:* all levels of environmental concern *Playfulness:* moderate to high
Description In the gamified version of the platform, users can receive points, and badges for activity on the portal. Various activities on the platform are rewarded with points. 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). For example, after reaching the first 1000 points in the area of water saving insights, users get the "smart saver"-badge (see Section 4.3.5.5 for detailed	

list of available actions and badges). Users can keep track of their performance in a status bar. The status bar also provides suggestions for actions to get more points, such as watching a video to learn more about water.

Second, users can win physical rewards. Due to the different characteristics and population size of the CH and ES case studies, two different approaches to award physical rewards are pursued. In both cases, earning virtual points enables users to win physical rewards.

CH case study:

As a reward for signing up and filling out the baseline questionnaire, all users can claim the board game 'Drop!' when they first login (50 points required = 1x login). When they continue to collect points, they can claim water saving gadgets (e.g. a water saving showerhead).

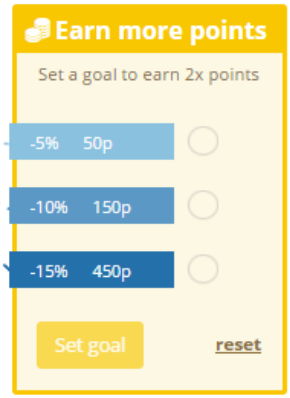
ES case study:

After performing a first set of actions and earning their first 5000 points on the portal, users can claim the board game 'Drop!' while copies are available.

Additional rewards can be won in weekly competitions, in which the top ranking user of the weekly leaderboard wins a ticket to the Oceanogràfic museum in Valencia, and an overall competition, which is decided after the first 9 months of the trial in Valencia. There, the top three of the overall leaderboard win an iPad each. See section 0 for the detailed competition rules.

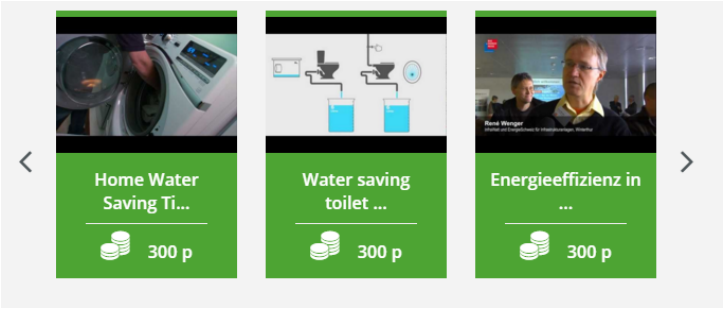
Earn points by reading water saving tips

Earn points by setting and achieving goals



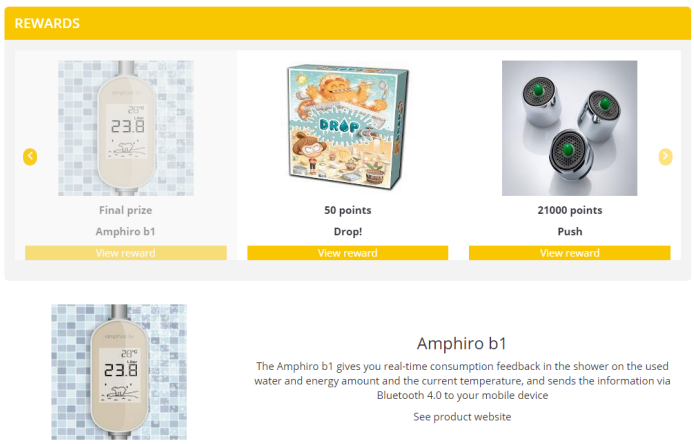
Status bar

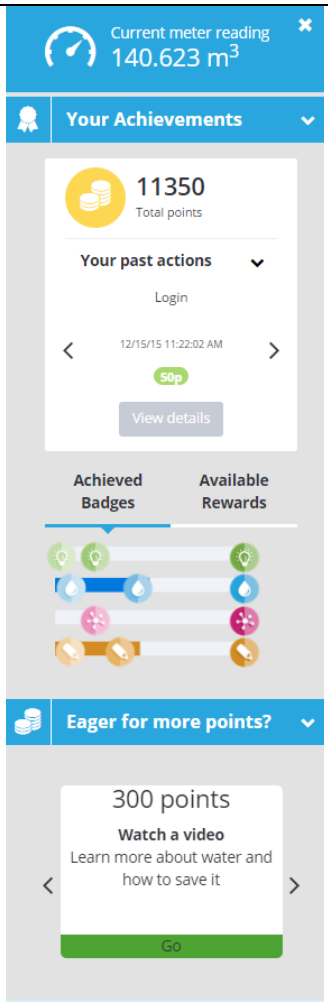
Collecting points by watching videos about water



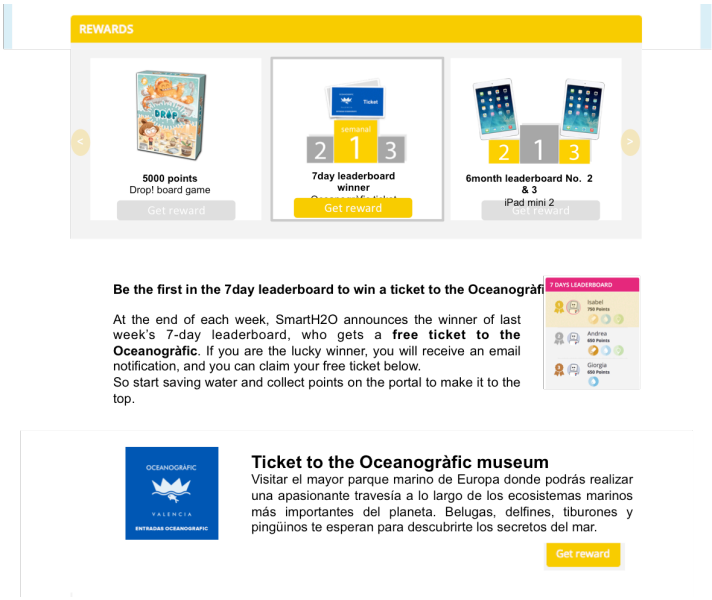
Incentivizing profile completion by means of points and a progress bar

Claiming physical rewards after collecting points (CH)





Claiming physical rewards after collecting points and winning competitions (ES)



Rationale

Throughout the behavioural change process, users need to be incentivized to be actively involved with water. Early in the process, awareness should be raised, and consequences of their actions should be highlighted, whereas in later stages positive behaviour should be reinforced. Longitudinal studies have shown that effects that have been achieved diminish over time (e.g. [Fielding, 2013; Stewart et al., 2013]). This highlights the importance of continuously reinforcing the motivation of users, in line with Skinner's reinforcement theory [Skinner, 1957; see 2.2.3]. Whereas existing studies on behavioural change processes primarily assume that the behaviour is an outcome of a rational process, the motivation to allocate cognitive resources is not only driven by rational thoughts, but also by hedonic values [Steg et al., 2014].

The user's hedonic goals have shown to be important determinants for environmental behaviour such as water consumption [Lindenberg and Steg, 2007; Steg et al., 2014], but the contribution to hedonic goals can also help to bootstrap the behavioural change process in itself. In SmartH2O we anticipate on the user's hedonic goals by means of gamification, the use of game design elements in non-game contexts [Deterding, 2011]. In early phases

of the behavioural change process, gamification is used to first extrinsically motivate users, before offering support to internalize the new behaviour and for intrinsically motivated new habits.

In both the Tegna pilot and the Valencia a physical reward (e.g. the Drop! Game) is provided as a result of collecting points. The Drop! board game is awarded after initial platform activity, such as filling out the user profile, filling out a sign-up questionnaire, and reading the first water saving tips in order to facilitate the on-boarding process and to provide users with a tangible reward for doing so.

This combination of virtual and physical rewards is necessary, because in the requirements elicitation phase we have found that users strongly differ in terms of their 'playfulness', the extent to which they want to engage in gameplay. The promise of physical rewards at the start of using the platform is important to also users who do not feel motivated by gameplay alone to engage in water saving actions on the platform they can get points for. Once they are on board, other non-game-like incentives are available to promote behavioural change for this class of users, e.g. setting water consumption goals, reading tips, and inspecting water consumption patterns.

The size of Valencian user base allows for a stronger integration of gameplay, user activity on the platform, and physical rewards. A user who ends up on top of the weekly leaderboard receives a museum ticket. This design draws on different user motivations: the basic desires for competition and collection (see basic desires theory, section 2.2.1; [Reiss, 2002], an opportunity for social comparison [Festinger, 1954] with other users through the leaderboard, and continuous reinforcement of positive behaviour [Skinner, 1957].

In the sections below we show how the gamification elements are integrated with actions and information that were designed to influence attitudes, beliefs, and behaviours. An elaborate explanation of the rationale behind the gamification approach has been provided in Section 2. The algorithms and rules are defined in Section 4.3.

4.1.3 Reinforcements through social rewards

Behavioural change phases	*Contemplation, Action, Monitoring*
Class of users	*Affinity w/ technology:* low affinity and higher *Affinity w/ data:* low affinity and higher *Environmental concerns:* low affinity and higher *Playfulness:* moderate and higher

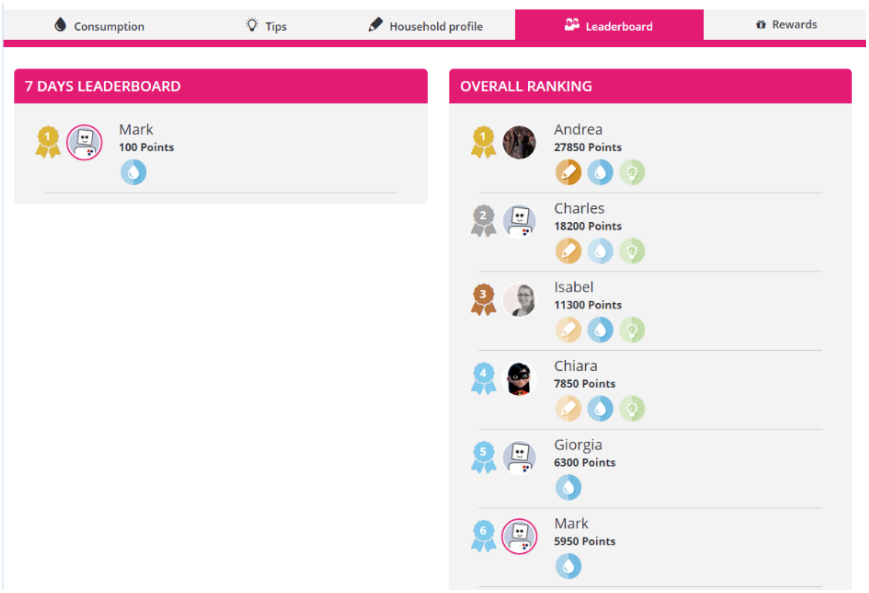
Description

A leaderboard is offered, containing both overall and last week's high scores, which highlights 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.

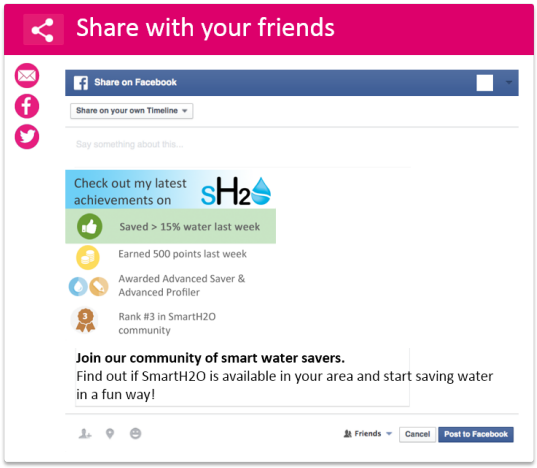
In the upcoming release, both individual achievements and a summary of achievements can be shared via mail, Twitter, and Facebook. Achievements are comprised of the percentage of water that is saved, and the badges and points that are collected. The post with the achievements that is shared also contains an invitation to the user's friends to sign up for the portal, if it is available in the area.

Finally, in the next release, users can compare their water saving performance against other households in the neighbourhood by clicking on icons on a map and inspecting their achievements.

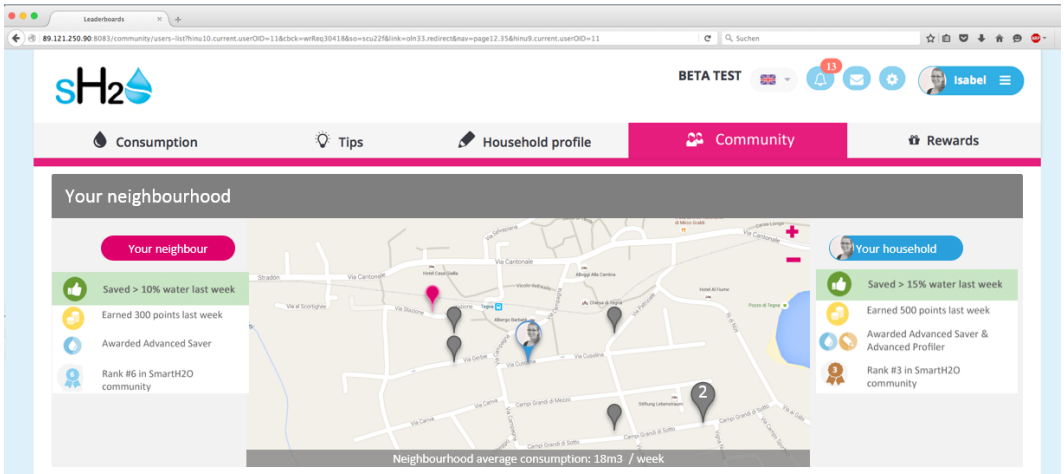
7 days leaderbord and overall ranking



Social sharing in upcoming release *(sharing via e-mail, and Twitter is also planned)*



Comparing your household's water saving against the neighbourhood (upcoming release)

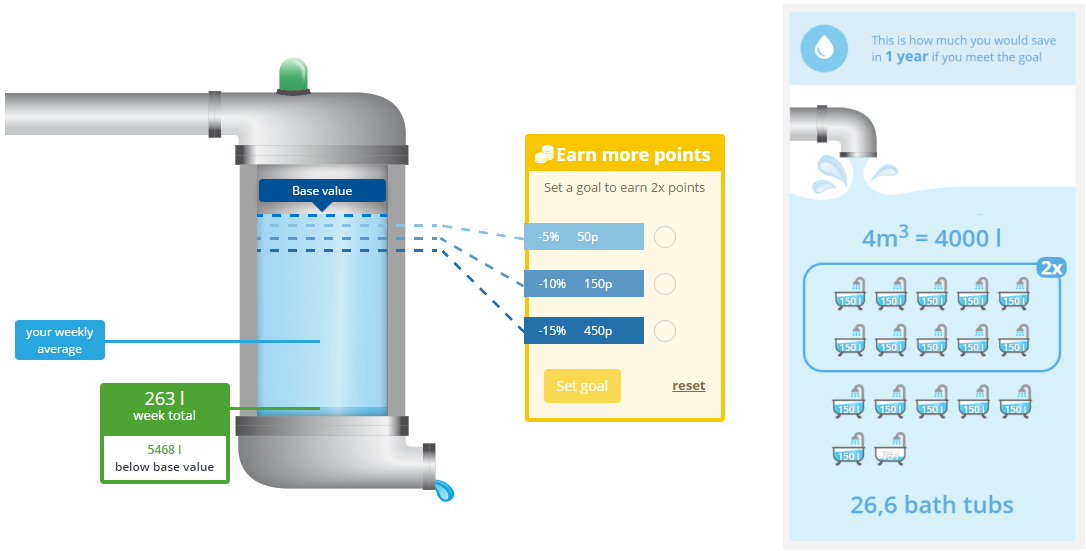


Rationale
The SmartH2O portal contains a leaderboard with overall and weekly high scores, highlighting the water saving performance of the top users. This encourages not only competition, but also opens up the opportunity to enhance the user's self-perception. According to social comparison theory [Vassileva, 2012; Festinger, 1954], people seek to evaluate and/or seek to get more positive beliefs about their own abilities by comparing themselves to others. Social rewards can provide an additional incentive as they fulfil the need for esteem in the Maslow hierarchy of needs [Maslow, 1943]. To extend opportunities for social recognition beyond the SmartH2O user base, and also to provide users who do not feel incentivized by gameplay to get recognition for their water saving performance, social sharing functionalities are planned. In the next release, the user can share their achievements on Facebook, or Twitter, and via e-mail. Finally, after the upcoming release, users can compare their performance against other users in their neighbourhood. This has three expected effects: 1) social recognition by important people from their network; 2) depending on the prevalence of water efficient behaviour, a positive social norm towards water saving can become visible to the whole neighbourhood, which motivates behavioural change for users who do not engage in water saving actions yet [Schultz et al., 2014], as users are sensitive to social influences, and to achieve normative goals (e.g. to do what is expected from them; [Lindenberg and Steg, 2007]).

4.1.4 Setting water saving goals

Behavioural change phases	Action, Monitoring
Class of users	*Affinity w/ technology:* low affinity and higher *Affinity w/ data:* low affinity and higher *Environmental concerns:* all levels of environmental concern *Playfulness:* moderate to high
Description	
Users can set water saving goals via the monthly and yearly consumption visualisation. The interface allows users to express their level of ambition with three options, ranging from a 5% to a 15% reduction. Points are awarded for setting and achieving the goals. The more ambitious the goal, the more points a user will receive. Impact of water saving is demonstrated by showing how many bathtubs filled with water users would save in one year's time when they achieve the goal.	

Setting goals in the water consumption pipeline visualisation, with water savings presented as the no. of bathtubs

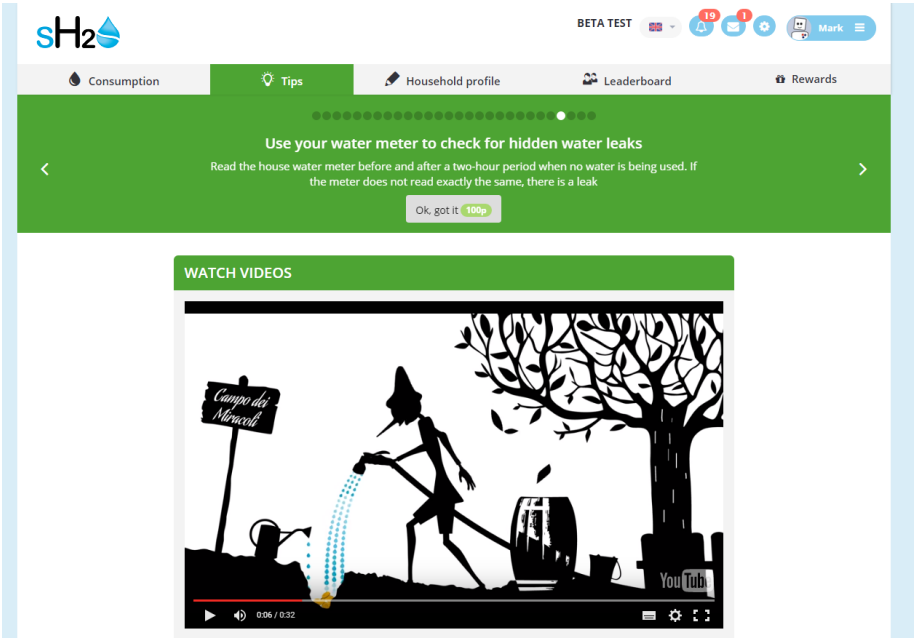


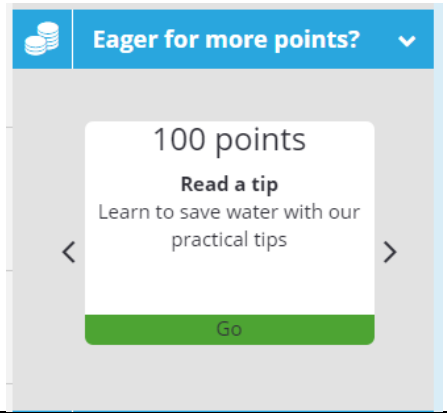
Rationale
Even though self-setting goals have shown promising results in the area of energy consumption (e.g. [Abrahamse, 2015]), this concept has received less attention in the area of water saving. Self-setting goals are expected to create commitment towards the target behaviour, in this case saving water. Not achieving these self-set goals causes cognitive dissonance, whereas achievement of the goals is, in terms of goal framing theory, expected to strengthen hedonic, normative, and gain goals of the user [Lindenberg and Steg, 2007]. Additionally, it is linked with the gamification: achieving goals yield points, which results in social recognition when the user is visible on either the last-week or the overall leaderbord. These social rewards are expected to motivate the user, on top of the aforementioned intrinsic motivators that come from goal achievement. An increase in intrinsic motivation [Deci and Ryan, 1985] is a prerequisite for forming new habits [Dahlstrand and Biel, 1997]. The bathtub visualisation positively affects a number of factors that predict the personal norms (which can be described as behavioural self-expectations) that according to the Norm Activation Model [Schwarzer et al., 1997; Harland et al., 2007] predict an individual's behaviour. Demonstrating how much you can save results in increased awareness of the consequences, a reduced denial of responsibility, a higher efficacy, and a higher situational responsibility. Finally, as explained in Section 2, the achievement of goals has inherent value for users. According to need achievement theory [Atkinson, 1960], and individual's self-perception is improved when he experience the success of achieving goals.

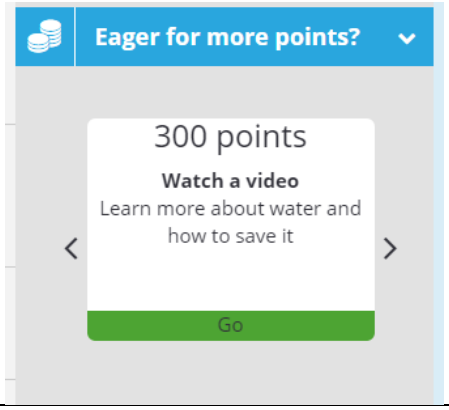
4.1.5 Water saving tips

Behavioural change phases	Precontemplation, action
Class of users	*Affinity w/ technology:* low affinity and higher *Affinity w/ data:* low affinity and higher *Environmental concerns:* all levels of environmental concern *Playfulness:* moderate to high
Description	

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.







Rationale

The water saving tips have two objectives: to increase the perceived behavioural control and to encourage social learning. According to the theory of planned behaviour ([Ajzen, 1991], see Section 3.1) and to self-efficacy theory [Bandura, 1977], see Section 2.2.1), the extent to which a user is confident that he can actually perform the desired behaviour affects the user's behavioural intention, and subsequently the behaviour itself. By providing concrete water saving tips, the user will feel more confident that he can actually save water, which affects the likelihood that the user will actually attempt to save water. This is important for the precontemplation phase in which users need to be persuaded that they have a role in saving water, as well as in the action phase in which users must get support to put their positive attitudes into practice.

The social learning theory [Bandura, 1977] takes a different perspective on acquiring new behaviour in the sense that not only beliefs and attitudes about the user's control determine

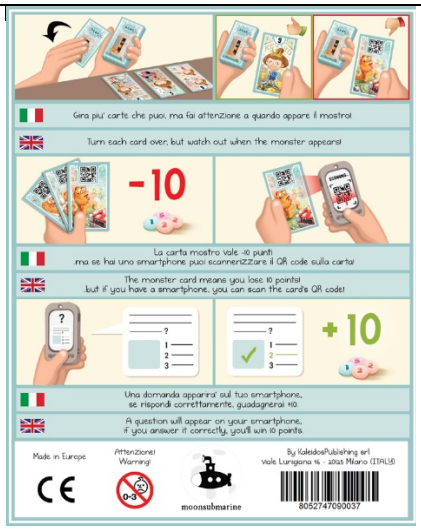
whether a user can carry out the behaviour, but also whether circumstances have enabled the user to *learn* the behaviour. The theory postulates that people acquire new behaviour through observation, imitation, and modelling. Maximal chance of adoption of the new behaviour is achieved when the following conditions are met: the subject must pay attention, must be able to store and/or retrieve examples of behaviour, must be able to practice the behaviour, and most importantly must be motivated to perform the behaviour.

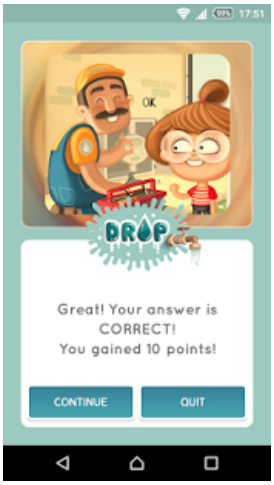
In the SmartH2O social awareness app, attention to the water saving tips is drawn both from the menu bar and from the status bar that displays performance in the system. Both brief textual tips and engaging videos are available that both demonstrate how exactly water can be saved. Users can always review tips they have read before. Water saving tips are available in both the basic version and the gamified version. In the gamified version, users are motivated to read the tips as they receive virtual (points) and ultimately physical (water saving gadget) rewards once they have collected a sufficient number of points (see Section 4.1.2). In both versions, users can review their activity by means of the status bar. If consumption has been reduced, this becomes visible in the water consumption visualisations (see Section 4.1.1)

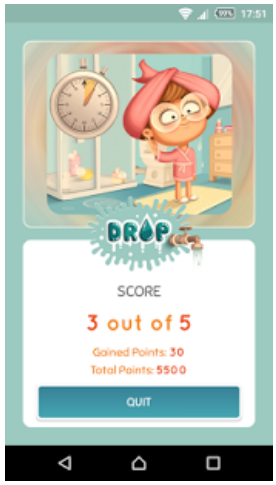
Fielding et al. [2013] have demonstrated in their field experiment that showing users how to save water indeed leads to lower levels of water consumption in the first year after exposure to this information. Ongoing reinforcements for engagement with water saving that take the shape of virtual and physical rewards are expected to result in a sustainable change in behaviour.

4.1.6 Incentivizing water saving by playing augmented games (Drop! game)

Behavioural change phases	Precontemplation, contemplation, action
Class of users	*Affinity w/ technology:* low affinity and higher *Affinity w/ data:* N/A *Environmental concerns:* all levels of environmental concern *Playfulness:* moderate to high
Description	
Drop! is a hybrid board and online game, designed for 3 to 6 players. The board game features Lill, a little girl who wants to save water, and a friendly monster who is clumsy enough to keep spilling water. The game comprises a set of cards with two distinct characters. Lily makes an effort to save water in various different ways (e.g., filling up the dish washer before using it, checking the status of pipes, reusing water); and a monster, lives in the armchair of Lily's bedroom and tries to reproduce the same savvy behaviour but is awkward and thus obtains the opposite effect (spilling water, wasting water in the garden, braking pipes, etc). Users take turns in drawing cards, trying to avoid the monster cards. For each Lily card, players get points, whereas for each monster are deducted. Users can recover the lost points with a mobile app: by scanning the QR-code on the monster card, users get a number of questions on their mobile. If they answer the question correctly, they can undo the deduction of points.	







Rationale

The Drop! game serves a number of different purposes. First, the game design was set up in such a way that it is a fun game to play with the whole family, appealing to the hedonic goals of the players, and framing engagement with water as something that can be fun.

By playing the game within a household, saving water becomes a topic of conversation. This is important, because not only the composition of the household is a strong predictor of water consumption [Jorgensen et al., 2009], but also the household water conservation *culture* [Fielding et al., 2012]. Raising water saving awareness and enabling social learning of water saving practices by providing concrete examples is expected to positively contribute to the household water conservation culture, which can lead to a decreased consumption.

In the contemplation phase, knowledge and resulting beliefs about water consumption have the potential of changing attitudes towards water conservation, which would in turn influence the behaviour. Playing the board game, and answering questions in the mobile app game increases the knowledge people have. People are incentivized to play the game in two distinct but related ways: the game design of the Drop! game itself, and the link with the gamified portal. That is, answering questions in the mobile game is awarded with points on the SmartH2O portal. Thus, playing the mobile game not only increases the knowledge about water alone, but also incentivizes users to become (more) active in the portal through which saving water is further stimulated.

Finally, in terms of goal framing theory [Lindenberg and Steg, 2007] the Drop! game activates normative goals: the user's desire to act appropriately. This is done by the sharp contrast between little Lily and the Monster, and the corresponding water saving and water spilling actions, strengthened by the game mechanics that associate water saving with achievement, and water spilling with losing.

A more elaborate conceptualisation of the Drop! game can be found in *D4.1 First social game and implicit user information techniques*.

4.2 Summary of incentive strategies in the two pilots

The preceding sections, we have highlighted the main incentives designed within the SmartH2Osocial awareness applications and games, and linked them to the background theories of motivation and behavioural change determinants. In doing so, we have observed that different variants of the base principles have been applied in the two pilots, due to their different characteristics. In this Section, we summarize the essential differences between the two pilots and how such differences have impacted the detailed definition of the incentive strategies.

The pilots in Tegna and Valencia have been developed and deployed in sequence (first Tegna, then Valencia), based on different local scenarios. Their major differences can be summarized as follows:

- **Technical scalability**: the number of potential pilot users in Valencia is 1000 times that of Tegna. In the Spanish case study, the Gamification Engine that realizes the incentives must be able to cope with a very large consumer base, which entails the logging and rewarding of a potentially very large set of internal and external actions. Even assuming the hypothesis that only 10% of the users engage, and perform only one action per day, this quickly brings the number of actions to monitor and turn into incentives over the number of 1.5M per year.
- **Budget constraints**: in a large-scale ***innovative*** pilot, where there is very little prior expertise on the achievable degree of engagement and participation of water consumers to the proposed activities, a competition-based approach to gamification with real world (and thus costly) rewards is potentially a challenge to the budget. Therefore, a realistic incentive system must be able to cap the budget investment in rewards, without jeopardizing the competition effect designed in the incentive system. In the Valencia test case, a number of real incentives are deployed, which have a non-negligible cost. The main outcome of this difference is that in the Valencia pilot, rewards are assigned to the users not in a first-come-first-served, continuous mode, but in a periodic way. Every period (e.g., week and month), the leaderboard is assessed and a finite, predefined number of users are awarded (e.g., the top 1, or the top 2). This different rewarding scheme retains the potential of stimulating competition, while placing a cap on the maximum number of rewards that must be granted.
- **Legal constraints**: a pilot deployed to the entire customer base is no longer a pilot, ***but is a real application***; therefore, further constraints descend from the relationship between the (public) water utility company and its customers (the citizens). The most prominent constraint is the impossibility of performing classic A/B testing of the interface and stimuli at such a large scale, because equal and fair competition rules must be granted to all participants; this requirement forbids sending different versions of the portal to randomly selected user groups and comparing the response to such alternative versions. Indeed, a user could complain (also legally) for not having achieved an objective or won an award due to a reduced version of the gamified system he was exposed to. Therefore, the incentive evaluation methodology must be defined in such a way to be able find a scientifically sound way to assess the impact of different incentive stimuli, despite the fact that all citizens must "see the same interface".

Table 4. Overview of main parameters and design decisions in CH and ES pilots.

	Swiss pilot	**Spanish pilot**
Population	400	400.000
Reward budget	1000 CHF	2500 €
External incentive type	Continuous, point-based	• Initial reward: point-based • Periodic-Weekly competition • Overall competition
Baseline calculation for consumption actions	Historical metered consumption (1/1/2013 – 31/12/2014)	Consumption measured during the 12 months prior to sign-up
Reward types and number of available copies	• Drop! board game • Amphiro b1 shower meters (10x) • Water saving shower heads (5x) • LED Shower heads (2x) • Other, smaller water saving appliances (20x)	• Initial (Drop! board game, 2000x) • Periodic-Weekly (Oceanographic ticket; 40x) • Final (iPad; 3x)
Reward repeatability by same user	• 1 reward type per user (not repeatable)	• 1 Drop! game per user • N Oceanogràfic tickets per user (repeatable) • 1 iPad per user
Mode of delivery	Shipment	Pick up at delivery point
Draw management	Not relevant, not competition-based	Heuristic rule explained in the terms and conditions
Vacation period management	Heuristic rule (only water consumption decrease below a given threshold is considered voluntary water saving and thus rewarded)	Heuristic rule (only water consumption decrease below a given threshold is considered voluntary water saving and thus rewarded)

4.3 Implementation of the incentives in the SmartH2O platform

The control of the delivery of incentives in the SmartH2Oplatform is centralized into a component called the **Gamification Engine**.

This component is described in detail in the document “Gamification Engine: User And Administrator Manual Version 3.0”, which has been produced as an addendum to the software deliverable D6.4 Platform Implementation and Integration - second prototype.

In this section we recap only the essential concepts and refer the reader to the full manual for the details.

The Gamification Engine “listens” to the actions of the user and transforms them into a variety of rewards, for improving activity and participation.

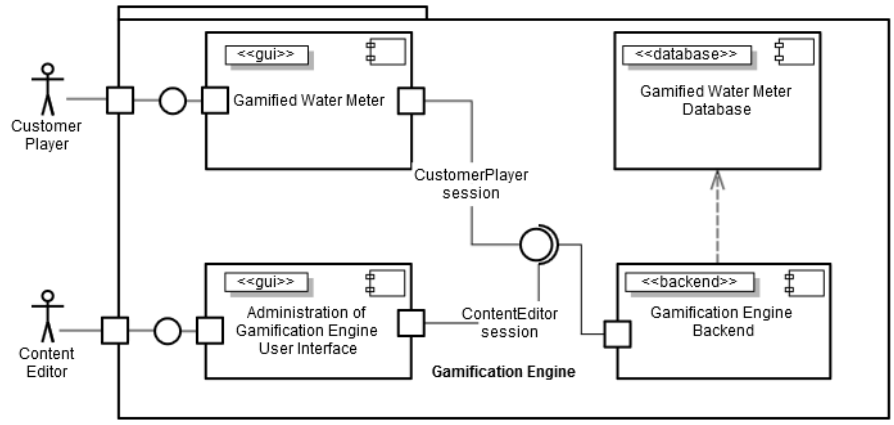


Figure 10. Gamification Engine component diagram.

As shown in Figure 10, the **Gamification Engine** is the central component that handles the communication with the main SmartH2Oplatform components and takes care of computing badges, achievements, rewards and all the other gamified features acting as incentives for behavior change.

Its core is the **Gamification Engine Backend**, which is a parametric rule engine transforming actions into points.

All the gamified data are 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.

A UI for the Administration of the Gamification engine allows the operator to set the parameters of the gamification rules interpreted by the GE:

The Gamification engine works as a rule-based engine; it takes inputs and produces outputs as illustrated in Figure 11. Its main responsibility is to receive the notification of actions performed by the user and decide if, and to what extent, such actions should be rewarded.

The main concepts of the GE are:

- **Gamified Customer Portal:** the GUI for customers that allows to explore gamified objects
- **GE Admin Portal**: the GUI for admins that allows the utility operator to configure gamified objects and monitor users.
- **Gamification objects**: game concepts composing the gamification mechanics (e.g. Action, Badge, Goal, Reward).
- **Thematic areas**: categories in which the gamification objects (action, badge areas) are grouped and organized. Examples of areas are: education, reputation, socialization and consumption.
- **Credits**: points the user (player) can earn performing actions on the platform.
- **Action**: a rewarded task the customer can perform on the platform (e.g. Read a tip, watch a video). Actions can be repeatable after a given time elapsed or can be set as not repeatable. Actions can be configured as enabled or disabled, setting them as active/inactive.
- **Badge areas**: category used to group badges related to the same topic, but with different levels (e.g. Super Profiler level 1 – Super Profiler level 2).
- **Badges**: virtual recognitions assigned to a user and visible to other users in the community, mostly used to demonstrate consumer status and progress. It is possible to define which actions contribute to achieve a given badge.
- **Goal**: consumption objectives that ca 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. A reward can be configured as available or not.

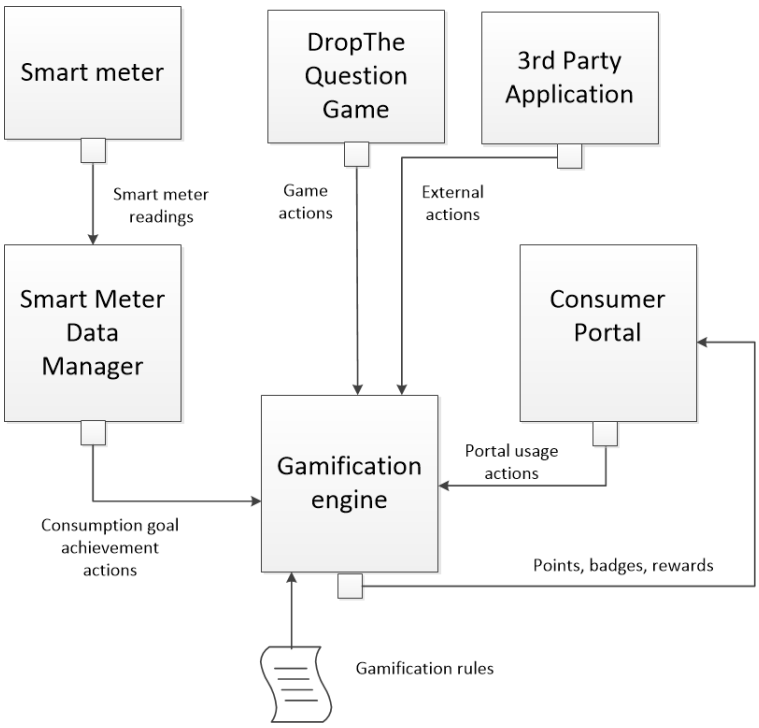


Figure 11. Input and outputs of the Gamification Engine.

4.3.1 Gamification Engine Objects and Parametric Algorithms

The GE is configured in both pilots so to group gamification objects (actions and badges) 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 readings. When the consumption data are received by the SMDM component, 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.
- **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.

Each action is characterized by a set of configuration parameters:

- "oid": <integer>: a unique identifier of the action.
- "name": <string>: a name for the action, meaningful to the user (e.g, “read a tip”).
- "description": <string>: a description of the action for the user.
- "area": <string>, name of the area associated to the action.
- "area_oid": <integer>, id of the area associated to the action.
- "score": <float>: the points earned performing the action.
- "check_time_elapsed": <boolean>: if true, a new instance of the action can be rewarded only after a time interval has elapsed since the last rewarded instance.

- "time_elapsed": <float>, null if check_time_elapsed=false: the interval duration for enabling action rewarding.
- "repeatable": <boolean>: if true the action can be repeated multiple times, otherwise it is considered only once.
- "active": <boolean>: if true the action can be considered, otherwise it is ignored.

The algorithms for action recognition and score assignment differ according to the source of the of action and the synchronicity of the rule engine computation.

Consumption actions are evaluated synchronously for all users, when the next batch of smart meter readings is acquired..

The parametric algorithm for weekly consumption action processing can be sketched abstractly as follows (the monthly version is similar):

```
On Monday at 6am
For each user U_j in the set of metered users MU
If reading frequency >= day
    Compute new weekly average NWA;
    For all active weekly goals WG_k of user U_j
      If NWA-Weeklybaseleine/Weeklybaseleine>= WG_k
        SatisfiedWeeklyGoals += WG_k;
    End for;

AchievedWeeklyGoal = max (SatisfiedWeeklyGoals);
For all goals G_i in AchievedWeeklyGoals
  Points_i = G_i.actionType.score;
  SendGoalNotification(U_j, G_i);
  U_j.profile.points+=Points_i;
  IncrementPointsInArea(U_j, "consumption", Points_i);
  UpdateBadges(U_j);
  UpdateRewards(U_j);
End for;

ResetGoals(U_j);
End for.
```

Figure 12. Abstract algorithm for synchronous weekly consumption action processing.

The other categories of actions of the GE 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 GE, according to the algorithm of Figure 13:

```
Loop:
When Action A_j of User U_i is received at the GE
If (A_j.Active=true AND
   (A_j.repeatable=true OR Count(U_i,A_j)=0) AND
   (A_j.check_time_elapsed=false OR A_j.timestamp-
    A_j.lasttimestamp > A_j.time_elapsed))
   Points = A_j.actionType.score;
   U_j.profile.points+=Points;
   IncrementPointsInArea(U_i, A_j.area, Points);
   UpdateBadges(U_j);
   UpdateRewards(U_j);
End loop.
```

Figure 13. Abstract algorithm for asynchronous user's action processing.

4.3.2 Rules parameters for action recognition and evaluation

The algorithms of Figure 12 and of Figure 13 are parametric with respect to the values of the configuration of the gamification engine objects: actions, badges, and rewards.

Table 5 illustrates the actions defined in the GE and the main configuration parameter (the Points) in each pilot.

Note that the value of the score property are not comparable across pilots, but are defined together with the value of the badges and rewards in that pilot; therefore, they should not be compared directly from one pilot to another one.

Table 5. Action sources in the Gamification Engine and their parametric value in the two pilots.

Actions	Source	Thematic area	Score in CH	Score in ES
Water saving actions				
Weekly savings:				
Weekly Savings 5% (automatic)	Consumption	Water Saving	50	1500
Weekly Goal 5% (set by the user)	Consumption	Water Saving	100	3000
Weekly Savings 10% (automatic)	Consumption	Water Saving	150	4500
Weekly Goal 10% (set by the user)	Consumption	Water Saving	300	9000
Weekly Savings 15% (automatic)	Consumption	Water Saving	450	13500
Weekly Goal 15% (set by the user)	Consumption	Water Saving	900	27000
Monthly Savings:				
Monthly Savings 5% (automatic)	Consumption	Water Saving	200	6000
Monthly Goal 5% (set by the user)	Consumption	Water Saving	400	12000
Monthly Savings 10% (automatic)	Consumption	Water Saving	600	18000
Monthly Goal 10% (set by the user)	Consumption	Water Saving	1200	36000
Monthly Savings 15% (automatic)	Consumption	Water Saving	1800	54000
Monthly Goal 15% (set by the user)	Consumption	Water Saving	3600	108000
Water saving insights				
Read water saving tip	Portal usage	Water Saving insight	100	100
Watch educational video / info graphic	Portal usage	Water saving insight	300	300

Correct answer on Drop!TheQuestion mobile app	Portal usage	Water saving insight	100	100
Login	Portal usage	Engagement	50	50
Download of Drop!TheQuestion mobile app	Game	Engagement	300	300
Switch from paper-bill to electronic bill	External	Engagement	–	2500
Notify a leak via Virtual Office mobile app	External	Engagement	–	100
Profiling actions				
Household profiling (100%)	Portal usage	Profiling	4000	400
Household profiling (60%)	Portal usage	Profiling	2000	200
Household profiling (30%)	Portal usage	Profiling	1000	100
Home profiling (100%)	Portal usage	Profiling	4000	400
Home profiling (70%)	Portal usage	Profiling	2000	200
Home profiling (40%)	Portal usage	Profiling	1000	100
Devices profiling (100%)	Portal usage	Profiling	4000	400
Devices profiling (60%)	Portal usage	Profiling	2000	200
Devices profiling (30%)	Portal usage	Profiling	1000	100
Filling out the questionnaire after signup	Portal usage	Profiling	–	2100
Participation actions				
Enter Top3 of overall Leaderboard	Portal usage	Engagement	200	200
Enter Top3 of 7 Days Leaderboard	Portal usage	Engagement	100	100

4.3.3 Rules parameters for badge assignment

A badge is a virtual reward, characterized by the following configuration properties:

- "id": <integer>, a unique identifier of the badge.
- "title": <string>, a name for the badge, meaningful to the user (e.g., “super saver”)
- "score": <float>, score required to obtain the badge
- "icon": <base64> icon that represents the achieved badge in the GUI.

Table 6. Badge levels per thematic area with point thresholds in the Gamification Engine in the two pilots.

Badges	Points in CH	Points in ES
Water saving		
Beginner saver	500	15000
Advanced saver	3000	45000
Super saver	7000	150000
Water saving insights		
Smart Saver	500	1000

Expert Saver	5000	5000
Guru Saver	25000	25000
Profiling		
Beginner profiler	1000	500
Advanced profiler	5000	1500
Super profiler	15000	4000
Participation		
Engager	500	1000
Influencer	2500	5000

4.3.4 Rules parameters for reward assignment

Rewards are physical goods that the user can redeem as a result of his actions. They are characterised by the following configuration properties:

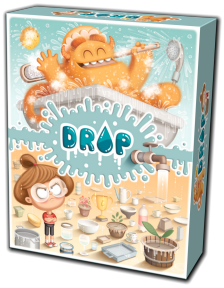
- "title": <string>, a unique name meaningful to the user.
- "description": <string>: a description text
- "needed_points": <float>, a number of points for redeeming the reward.
- "available": <boolean>,: the availability status of the reward. If false the reward is temporarily out of stock.

Table 7. Rewards available and points needed for redemption in the Swiss pilot.

Rewards in CH	Image	Points needed in CH
Drop! Board game: Drop! Board game for all ages. Learn more about water consumption with Lily and the Monster.		50
Push When installed, pushing the “Push”-button reduces your tap water consumption by 50%.		21000

Cascade Cascade permanently reduces your tap water consumption by 50%.		21000
Ecobooster Showerhead The Ecobooster switches the water consumption of your shower to eco-mode with a simple button.		25000
Shower LED This cool LED light shower sets the mood with seven different colours that change automatically and independently of the water temperature. No battery necessary.		60000
Amphiro b1 The Amphiro b1 gives you real-time consumption feedback in the shower on the used water and energy amount and the current temperature, and sends the information via Bluetooth 4.0 to your mobile device.		80000

Table 8. Rewards available and condition needed for redemption in the Spanish pilot.

Rewards in ES	Image	Needed in ES
Drop! Board game Push your luck with the Drop! Board game for all ages and get to know Lily, the wise little water saver, and the Monster, who always wastes water. Have fun with the whole family and learn about water and sustainability.		5000 points
Ticket to Oceanogràfic Visit the largest marine park in Europe where you can make a fascinating journey along the most important marine ecosystems. Belugas, dolphins, sharks and penguins are waiting for you to discover the secrets of the sea.		Weekly competition prize
iPad mini 2 Win one of two iPad mini 2, Apple's the second generation iPad Mini tablet computer. Whether you want to use it to play games with the whole family, watch videos, read your favourite books or contact family and friends.		9 month competition prize (2nd and 3rd)
iPad air 2 Win our grand prize, an iPad Air 2, Apple's sixth-generation iPad tablet computer. Whether you want to use it to play games with the whole family, watch videos, read your favourite books or contact family and friends.		9 month competition prize (1st)

4.3.5 Terms and conditions of the gamification

A large-scale competition such as the one launched in Valencia requires the users to be informed with precision of the “rules of the game”. Therefore, the gamification rules of the Spanish pilot are explained in detail to the users on a separate page of the portal, (see Figure 14).

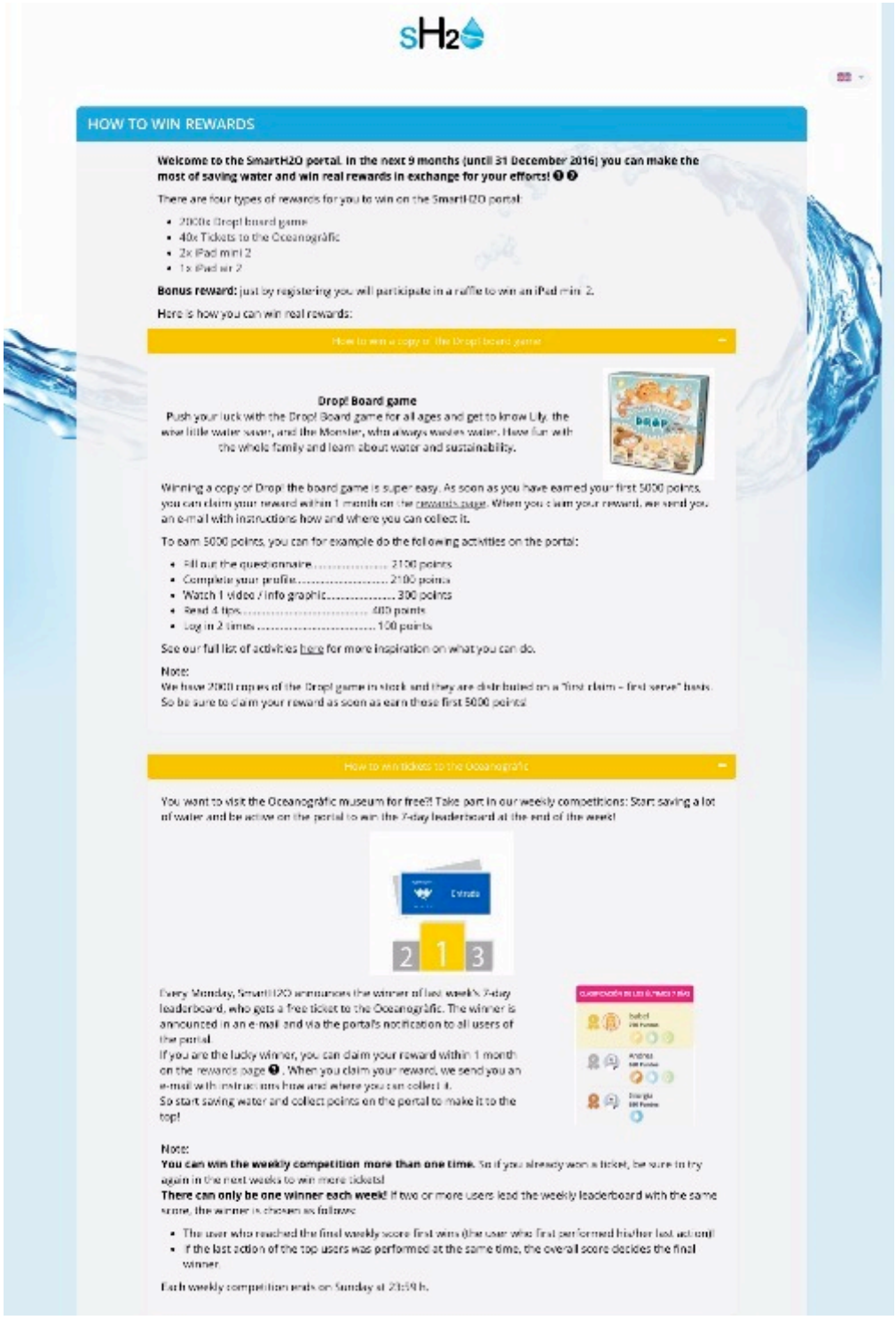


Figure 14. Rules page in the consumer portal.

The next subsections present the detailed text of the competition terms and conditions, exactly as presented to the users.

4.3.5.1 Rules page introduction

Welcome to the SmartH2Oportal. In the next 9 months (until 31 December 2016) you can make the most of saving water and win real rewards[1][2] in exchange for your efforts!

There are four types of rewards for you to win on the SmartH2Oportal:

- 2000 x Drop! board game
- 40 x Tickets to the Oceanogràfic
- 2 x iPad mini 2
- 1 x iPad air 2

Bonus reward: just by registering, you will participate in a raffle to win an iPad mini 2.

Here is how you can win real rewards:

4.3.5.2 How to win a copy of the Drop! board game

Drop! Board game

Push your luck with the Drop! Board game for all ages and get to know Lily, the wise little water saver, and the Monster, who always wastes water. Have fun with the whole family and learn about water and sustainability.

Winning a copy of Drop! the board game is super easy. As soon as you have earned your first 5000 points, you can claim your reward for 1 month on the rewards page. When you claim your reward, we send you an e-mail with instructions how and where you can collect it.

To earn 5000 points, you can for example do the following activities on the portal:

- Fill out the questionnaire…… 2100 points
- Complete your profile……..…….…. 2100 points
- Watch 1 video / info graphic……..…….. 300 points
- Read 4 tips……..…… 400 points
- Log in 2 times ……..…….. 100 points

See our full list of activities here for more inspiration on what you can do.

Note:

We have 2000 copies of the Drop! board game in stock and they are distributed on a “first claim – first serve” basis. So be sure to claim your reward as soon as earn those first 5000 points!

---

1 Workers of Aguas de Valencia Group are not allowed to win rewards.

2 The SmartH2O portal is the first version of a product from an R&D project. The availability of SmartH2O features and rewards also depends on the characteristics of the metering infrastructure of each household.

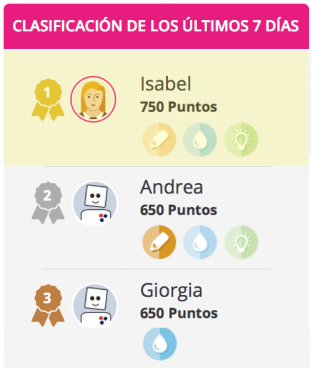
4.3.5.3 How to win tickets to the Oceanogràfic

You want to visit the Oceanogràfic museum for free?! **Take part in our weekly competitions:** Start saving a lot of water and be active on the portal to win the 7-day leaderboard at the end of the week!

Every **Monday**, SmartH2Oannounces the winner of last week's 7-day leaderboard, who gets a **free ticket to the Oceanogràfic**. The winner is announced in an e-mail and via the portal's notification to all users of the portal.

If you are the lucky winner, you can claim your reward on the rewards page[3]. When you claim your reward, we send you an e-mail with instructions how and where you can collect it.

So start saving water and collect points on the portal to make it to the top!



Note:

You can win the weekly competition more than one time. So if you already won a ticket, be sure to try again in the next weeks to win more tickets!

There can only be one winner each week! If two or more users lead the weekly leaderboard with the same score, the winner is chosen as follows:

- The user who reached the final weekly score first wins (the user who first performed his/her last action)!
- If the last action of the top users was performed at the same time, the overall score decides the final winner.

Each weekly competition ends on Sunday at 23:59 h.

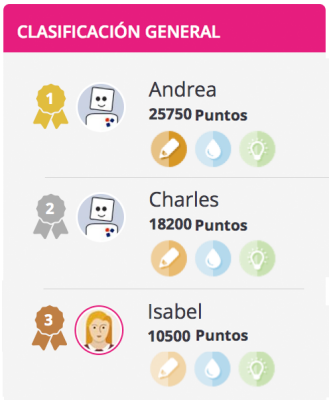
4.3.5.4 How to win an iPad

Win one of our main prizes in the **final competition!** Save the most water and be the most active on the portal to make into the final three of the overall leaderboard!

[3] Rewards are available **for the duration of one month after achievement**. Unclaimed rewards will be sent back to the pool of available prizes, and the winner cannot claim them any longer.

After 9 months (December 31, 2016), SmartH2Orewards the **final top 3 users of the overall leaderboard with an iPad each**:

- **iPad air 2** for 1st ranking user
- **iPad mini 2** for 2nd and 3rd ranking users



The final winners are announced via e-mail and the portal's notification system to all users of the portal.

In addition, there will be a final ceremony, where the overall competition rewards will be handed out to the winners..

If you are one of the lucky winners, you can claim your reward on the rewards page. When you have claimed your reward, we send you an e-mail with details of when and where the reward ceremony will take place.

So start saving water and collect as many points as possible on the portal to make it to the top!

Note:

There can only be 3 final winners! In case of a draw, the winners are chosen as follows:

- The final ranking is determined by who reached the final score first (the users who first performed their last action)!
- If the draw remains, the winners will be determined in a public lottery.

4.3.5.5 How to earn points on the portal

On the portal, you can do the following actions to earn points in 4 different thematic areas:

Water saving actions

Weekly savings:	**Points**
Weekly Savings 5%	1500
Weekly Goal 5%	3000
Weekly Savings 10%	4500
Weekly Goal 10%	9000
Weekly Savings 15%	13500
Weekly Goal 15%	27000

Monthly Savings:	
Monthly Savings 5%	6000
Monthly Goal 5%	12000
Monthly Savings 10%	18000
Monthly Goal 10%	36000
Monthly Savings 15%	54000
Monthly Goal 15%	108000

Available Badges:	**Beginner saver**	**Advanced saver**	**Super saver**
Needed score:	15000 points	45000 points	150000 points

Water saving insights

	Points
Read water saving tip	100
Watch educational video	300
Login	50
Correct answer on Drop!TheQuestion mobile app	100
Download of Drop!TheQuestion mobile app	300
Switch from paper-bill to electronic bill	2500
Notify a leak via Virtual Office mobile app	100

Available Badges:	**Smart Saver**	**Expert Saver**	**Guru Saver**
Needed score:	1000 points	5000 points	25000 points

Profiling actions

	Points
Household profiling (100%)	700
Home profiling (100%)	700
Devices profiling (100%)	700
Filling out the questionnaire after signup	2100

Available Badges:	Beginner profiler	Advanced profiler	Super profiler
Needed score:	500 points	1500 points	4000 points

Participation actions

	Points
Enter Top3 of overall Leaderboard	200
Enter Top3 of 7 Days Leaderboard	100

Available Badges:	Engager	Influencer
Needed score:	1000 points	5000 points

5 Testing of incentive models and algorithms in SmartH2O

To test the main elements of the incentive model in Valencia, where a large population can be targeted but may introduce otherwise unforeseeable dynamics, we have applied the ABM simulation (WP3). This way, we can better assess the possible impact of the leaderboard, the weekly competition and the Drop! reward for initial activity for a larger user base. Based on the results of the survey distributed in Ticino (WP5), we also consider the possible impact of badges as symbolic incentives. In addition, we consider the effect of visualization and hedonic design as incentives based on initial feedback from basic SmartH2Oportal users in the CH pilot, and evaluate the logs of the CH pilot with respect to the effect of different incentive types.
The full results from the CH and ES pilots will be reported in D7.2 and D7.3.

5.1 Simulation of incentive model dynamics

The developed agent based model (ABM for short), based on the water consumption simulator from WP3, is a simulation tool for evaluating the incentive model used in the gamified portal. More specifically, it aims at estimating the leaderboard and weekly competition dynamics, including the number of possible draws in a given competition under different scenarios of reward systems, expected point distribution among users over time and at the end of specified trial periods, as well as expected activity rates. In doing so, it explicitly takes into account the interaction mechanism underlying the adoption of the portal, and thus the propagation of signals among individual users and their responsiveness to possible adoption campaigns.

The agent based model for simulating water consumption developed in the WP3 and presented in the forthcoming deliverable D3.4, takes inspiration from the FIRMABAR model that has been applied to the Metropolitan region of Valladolid [Galán et al., 2009]. This model is a tool integrating social sub-models with models of urban dynamics, water consumption, and technological and opinion diffusion. What matters for the reward simulator, is that the ABM from WP3 mimics the FIRMABAR model for the Valladolid area by incorporating

- a Bass' model, coupled with a SIRS diffusion model, used to reflect the influence for the water demand of the adoption and diffusion of new technological devices
- a Young diffusion model to simulate the process of embracing a certain consumption behaviour because of the influence by the number of neighbouring adopters (hence giving rise to positive reinforcements).

5.1.1 General model structure

The agent-based model simulates the use of the gamified platform, and thence the possible actions an agent can perform in the aim of winning points. It includes the following agent types:

- a Main Agent (MA): it is used to moderate and synchronise the simulation;
- a Supplier Agent (SA): it represents the utility, who is also in charge of the portal,
- the Household Agents (HA), each representing a single household.

The simulation starts with the SA initiating a campaign for the adoption of the portal. Thence, a SIRS/Bass diffusion mechanism models the propagation of the portal adoption among household and a Young diffusion model is used to reflect the process of embracing a eco-friendly consumption behaviour among the platform users.

The water-demand/portal cycle involves the following sequence of interactions.

1. At each time step (in our case each day) SA asks each HA to determine her own water demand.
2. In response to this, each HA calculates its daily water consumption, and, if she is an

adopter of the portal, she determines the sequence of actions she wants to perform on the portal (like reading a tip or watching a video). At the beginning of each week and of each month, HA can also decide whether to fix a consumption goal or not.

3. At the end, SA collects all individual demands for water, calculates the total consumption and if applicable, calculates the number of points the household has gained thorough her daily actions and consumption behaviour.

5.1.2 Model characteristics

Households are assumed to belong to the same consumption class. Their consumption is stable when they do not use the platform while once on the platform, water consumption can be reduced of 5% depending on the chosen behaviour. This value (5%) corresponds to the average improvement in water use efficiency of adopters of WaterSmart (http://www.watersmart.com/measurable-results/).

The parameter of the diffusion model (see Figure 15) for simulating the adoption of the portal are tuned so that the trajectory of the system reaches an equilibirum corresponding to the 25% of the overall population. More precisely, according to the diffusion model, from a certain point on, the percentage of the users registered on the portal (users with different activity levels) will always coincide with the 25% of the overall population. The value of 25% corresponds to the percentage of households among the Valencia population currently using the EMIVASA portal. Table 9 lists the chosen parameter values.

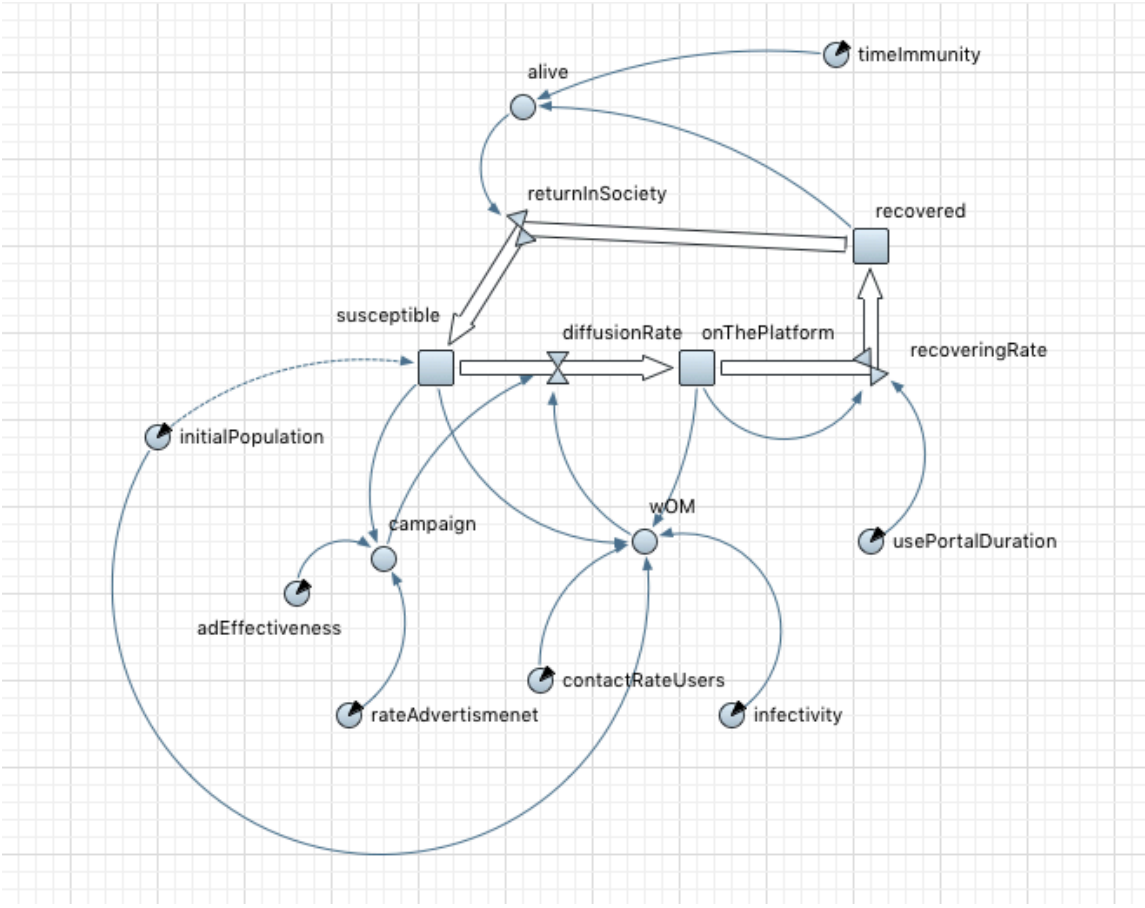


Figure 15. The structure of the diffusion model.

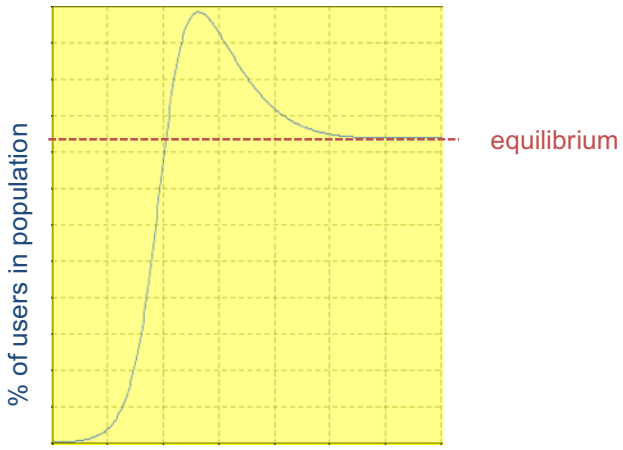


Figure 16. Example of trajectory over time of the diffusion model.

Table 9. Main parameter values.

Parameter of the Bass/SIRS model	Value
Adv. Effectiveness:	10%
Adv. rate:	0.0333 (once per month, e.g. in the monthly bill)
Contact rate users:	1/7 (once per week)
Infectivity:	2%
Use portal duration:	3 months
Time Immunity:	3 weeks

The parameters of the Young diffusion model are the same as the one used in [Galán et al., 2009]. The only additional parameter is the number of households "born" with a positive attitude towards a more conscious water saving behaviour once on the platform, and that thus can act as diffusor of a positive consumption behaviour. Based on the data coming from the results of the questionnaires among CH case study users of WP5, 10.78% of the households born with such a "positive behaviour" gene.

The possible daily actions of portal users with associated probabilities based on the data coming from CH case study users and from the users of the WebRatio Portal are shown in

Table 10. Daily portal actions and associated probability.

Daily portal actions	Associated probability
To log in,	5.4%
To read a tip,	3.5%
To watch a video,	2.5%
To fill in 30% of the profile	31%
To fill in 60% of the profile	22%
To fill in 100% of the profile	15%
To answer the questionnaire,	30%
To download the Drop App	7%

The number of daily correct answers to Drop questions is given by a uniform discrete distribution, with min=0, max=4

For selecting a self-set goal (both weekly and monthly), the probability has been settled at 10%. The goal is thence chosen according to a normal distribution with mean 5%, which once more corresponds to the average Water consumption reduction of WaterSmart users.

The limit of available tips (25) and videos (8) were also based on the number coming from the CH case study portal.

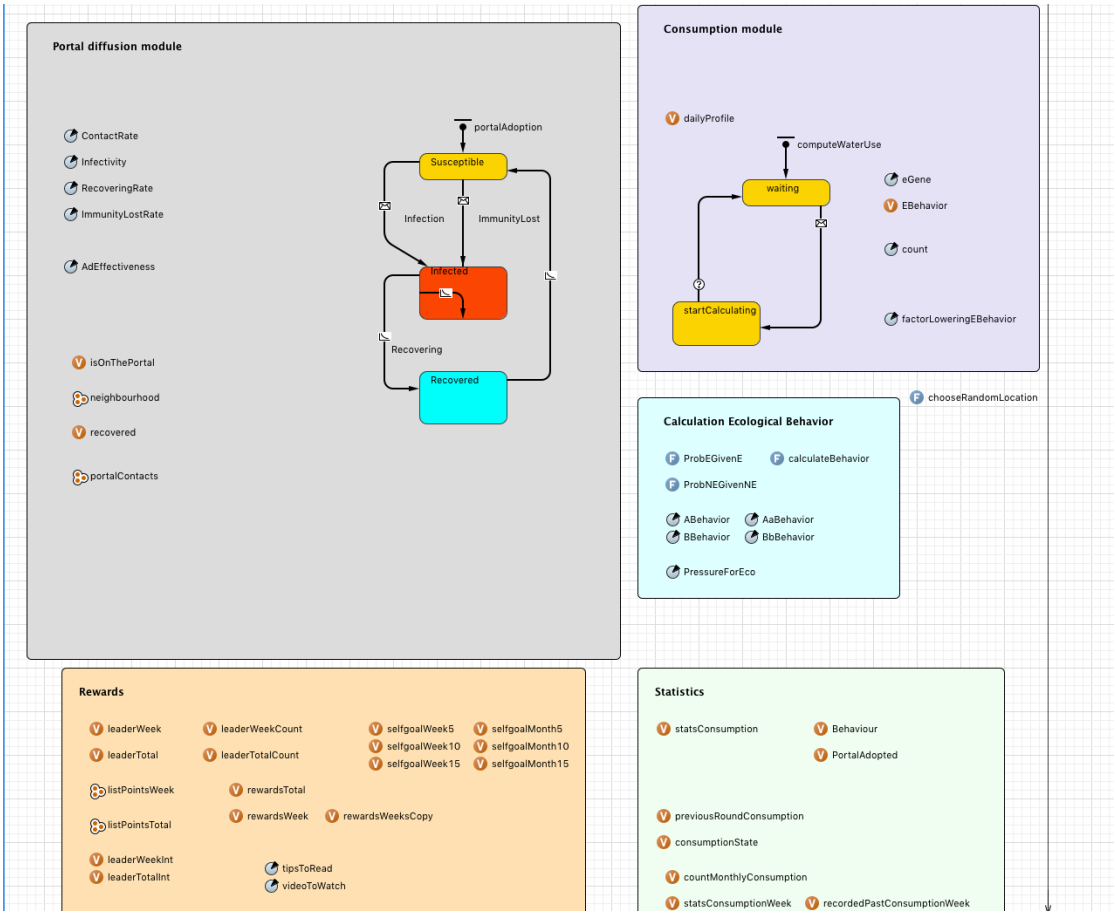


Figure 17. a view of the reward model interface.

5.1.3 Simulation and outcomes for individual incentive elements

The main objectives of applying the simulation in this context were to test the overall effect of main elements of the incentive model and its variations, e.g. to see whether they potentially ensure balanced point scores amongst new and already active users, few draw occurrences of top ranking users, and changing dynamics that could be observed over time.

Weekly leaderboard dynamics and draws

The first aspects that were considered in order to check the incentive model applied in Valencia were the weekly leaderboard dynamics. To be able to offer weekly competitions, it should be ensured that draws for first place in the leaderboard would not occur too frequently, and that such a competition would not just favour new users, but ensure lasting dynamics in which also existing users had a chance to earn enough point through continuous activity, most importantly through saving water. For this, the different water consumption point schemes were simulated under varying conditions, as the initial assumption was that a more

granular weekly consumption reward system could lower the risks of occurring draws in the weekly competition:

The ABM was applied in a series of simulations with different agent populations (2000 vs. 6000 household agents) and for the three different water consumption reward scenarios (see below). A simulation covers one year.

As described in the previous section, the parameters concerning the frequency of actions were, when available, based on the preliminary data coming from the CH pilot and from users of the Webratio portal. However, since we assume the ES pilot population to be different e.g. in terms of demographics, with more young people and a larger user base, other simulations were also performed by increasing the value of both the probability of logging into the portal, of performing the action of watching a video and of reading a tip (medium increment: [10%, 5%, 5%] and high increment: [50%, 10%, 10%]).

The three basic reward scenarios were based on the structure of the (weekly) reward system for lowering the water consumption:

a. 5% step consumption decrease and non-linear point assignment.
b. 5% step consumption decrease and linear point assignment.
c. 1% step consumption decrease and linear point assignment.

In general, to reduce draws as much as possible, the most granular, 1% step reward system appeared to perform best. However, simulating the other two scenarios resulted in similar outcomes; with the non-linear system performing slightly better than the linear one (see Table 11), and neither could prevent draws completely.

Table 11. Draws for different water saving level scenarios.

			Occurring draws for different water saving level scenarios		
Population	**Runs**	**Parameter probability**	**5%, non-linear**	**5%, linear**	**1%, linear**
2000	15	CH pilot activity	10,33	10,6	7,6
6000	12		13,42	15	10,08
2000	15	Medium increment	7,07	7,27	5,33
6000	12		8,75	8,83	7,92
2000	15	High increment	3,73	4,27	3,67
6000	12		4,5	6,3	4,5

By increasing the concerned parameter probabilities, i.e. by assuming a more active population:

- the average number of draws decreases in all three scenarios,

- as well as the differences between the three averages (NB - within the 5% step scenario - the non-linear system seems to perform always a bit better than the linear one. The same holds for the 1% step scenario compared to the 5% step scenario).

Based on these outcomes, it was decided to apply the 5% non-linear point distribution to gamify water consumption in the SmartH2Oportal. It will ensure a simplified user interface showing only 3 saving levels (5%, 10% and 15%) as compared to the 1% step scenario which would require at least 15 individual saving levels, as well as a slightly lower probability of occurring draws as compared to 3 saving levels with linear point distribution.

Therefore, for simulating additional incentive effects, the 5% non-linear point distribution was applied for 6000 agents. We also assume a higher activity rate as compared to the CH case study, due to a significantly different population, which has e.g. already been introduced to a consumption monitoring system (virtual office) in previous years where additional services like the paperless bill are offered. And since the portal will be linked to the existing system, users are expected to log into the portal more often. Relatively high download numbers of the new virtual office mobile app (>1000 downloads in 10~ months) also show there is a user

base that is fairly technology-affine and likely to be more active than in the CH case study. So as the basis for the additional simulations of the incentive schemes, we apply the bigger probability increment (+50% login probability/ +10% reading tips probability/ +10% watching videos probability) to the basic probabilities we obtained in the CH case study for all runs simulating possible behaviour in Valencia. This means that if users in CH on average would log in 10 times per month, users in Valencia on average would be expected to log in 15 times per month.

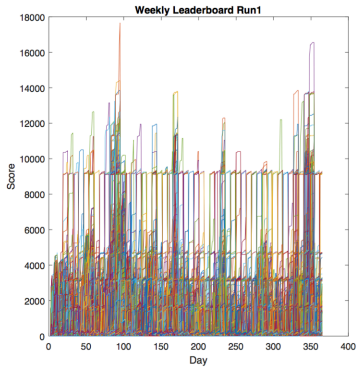
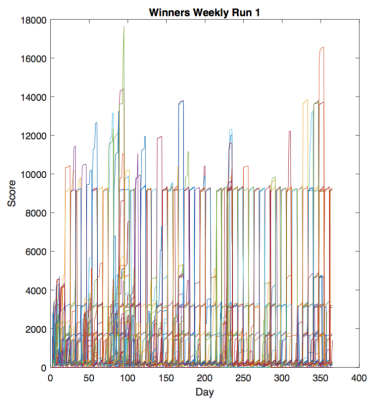
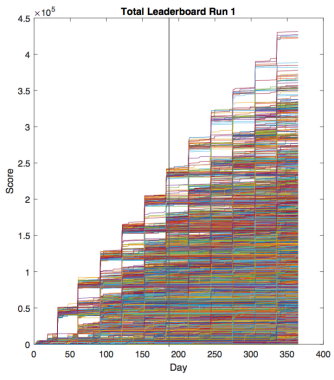
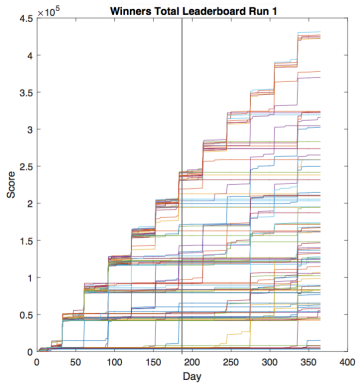
Table 12 shows the average no. of users who ranked first at least for one day in the weekly leaderboard for 15 runs. The outputs show that there is a sufficient interchangeability of weekly leaderboard winners, meaning that the risk of having someone winning multiple times appears to be limited. The figures below show exemplary outputs of the simulation with respect to the weekly and overall leaderboard development. We considered:

- A1) Weekly leaderboard development over one year: point score development of all simulated users.
- A2) Weekly leaderboard development over one year: point score development of all simulated users who ranked first at least for one day in weekly leaderboard.
- Figures B1) and B2) illustrate that during the simulations, there were also only few top ranking users at the end of a 6 months period.
- B1) Total leaderboard development over one year: point score development of all simulated users.
- B2) Total leaderboard development over one year: point score development of simulated users who ranked first, second or third at least for one day in total leaderboard.

Table 12. No. of users who ranked first at least for one day in weekly leaderboard.

Run	No. of users who ranked first at least for one day in weekly leaderboard	% of total population
1	172	2,87
2	191	3,18
3	199	3,32
4	205	3,42
5	211	3,52
6	240	4,00
7	197	3,28
8	177	2,95
9	208	3,47
10	177	2,95
11	202	3,37
12	205	3,42
13	160	2,67
14	160	2,67
15	207	3,45
Average	**194,07**	3,23

Table 13. Exemplary runs showing the development of the total and weekly leaderboard.

	1 (all users)	2 (winners only)
A) Weekly leaderboard		
B) Overall leaderboard		

Weekly activity and point distribution dynamics

The following figure shows the activity level over time (=average number of active users).

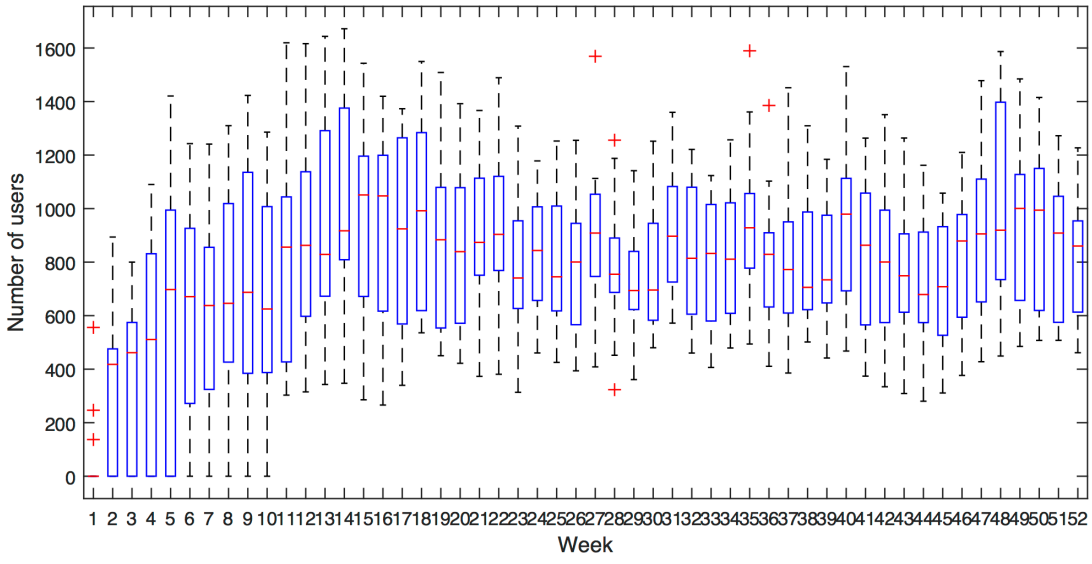


Figure 18. Average number of weekly active users over time.

The following figures show the average point distribution among users for a simulation period of 6 months (see Figure 19) and 12 months (see Figure 20), showing a large portion of users in the first interval with 0-5000 Points (after 6 months) or 0-10000 Points (after 12 months) and very few top ranking users. As Table 14 shows, on average, after 6 months, 3599,87 of 6000 users would reach at least 5000p (Drop! game reward available).

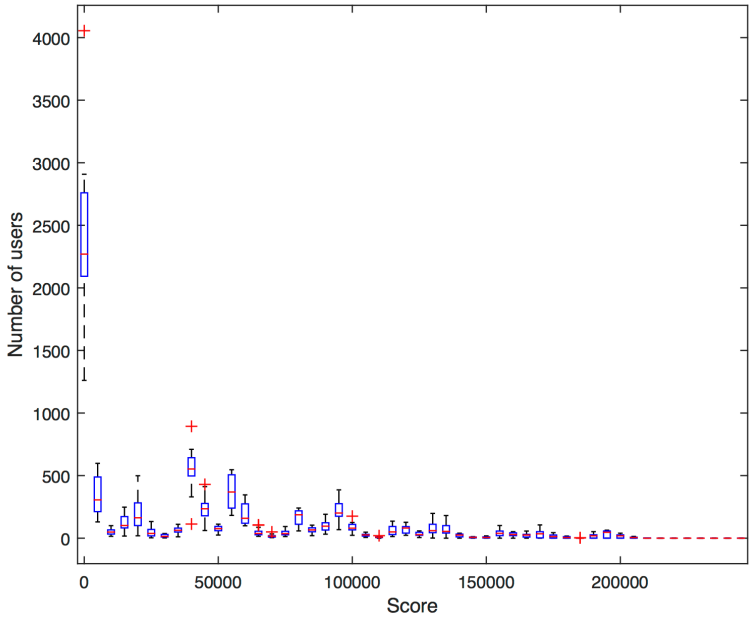


Figure 19. Point distribution after 6 months (interval size = 5000 points).

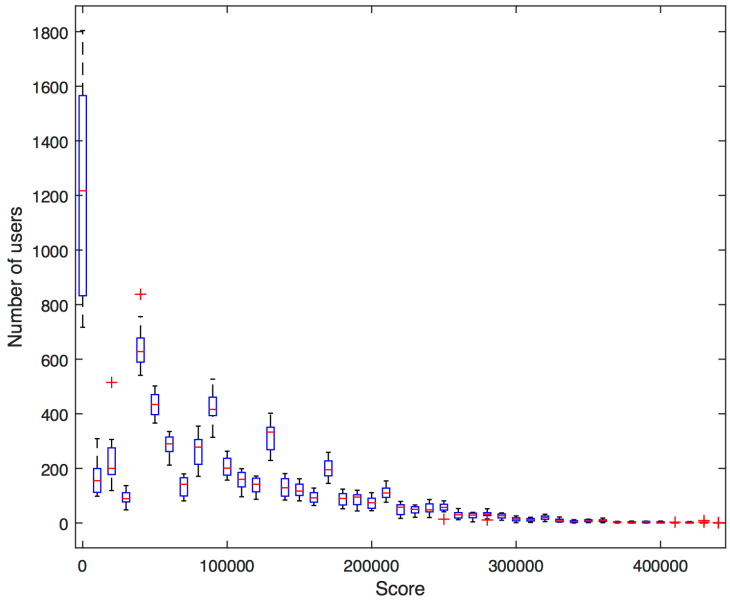


Figure 20. Point distribution after 12 months (interval size = 10000 points).

Table 14. No. of Drop! winners after 6 and 12 months.

Runs	No. of potential Drop! winners after 6months (>5000p)	No. of potential Drop! winners after 12months (>5000p)
1	3082 (51,37%)	4562 (76,03%)
2	4017 (66,95%)	4820 (80,33%)
3	3722 (62,03%)	5380 (89,67%)
4	3583 (59,72%)	4946 (82,43%)
5	3914 (65,23%)	5492 (91,53%)
6	3840 (64%)	5302 (88,37%)
7	3883 (64,72%)	4850 (80,83%)
8	1942 (32,37%)	4695 (78,25%)
9	4253 (70,88%)	5118 (85,3%)
10	4736 (78,93%)	5343 (89,05%)
11	3247 (54,12%)	5314 (88,57%)
12	3538 (58,97%)	5358 (89,3%)
13	3833 (63,88%)	4751 (79,18%)
14	3173 (52,88%)	4889 (81,48%)
15	3235 (53,92%)	4508 (75,13%)
Average	3599,87 (60%)	5021,87 (83,7%)

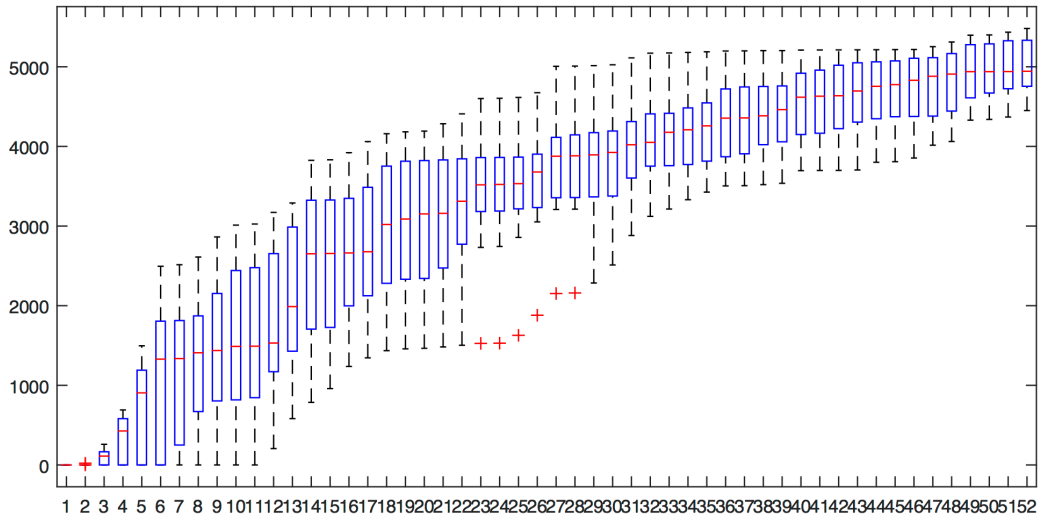


Figure 21. Average no. of users reaching 5000p over time (potential Drop! winners).

Observed activity effects of weekly competitions in the simulation

We have checked possible dynamics in the leaderboard, and the resulting point distribution among users. In a next step we considered possible effects of a weekly competition on the portal, which would be based on the leaderboard: Each week, the winner of the weekly leaderboard receives an external reward (ticket to museum), and the competition results will be announced via e-mail to all portal users.

While the previously applied model only considered a general advertisement campaign once a month with 10% effectiveness, the weekly email announcement of the previous week's competition winner would be expected to also have an advertisement effect on users, as a kind of personal advertisement campaign. In order to model this, we introduced two additional parameters:

- Personal Ad. Effectiveness.
- Personal Ad. Rate.

The Personal Ad. Rate would be 1/7 (once per week), and for the Personal Ad. Effectiveness, we selected 20%, assuming 2x the effectiveness of the overall ad. campaign, which was set to be 10% (see 4.1.2 Model characteristics).

Table 15 lists how many people would be registered to the portal in the long term (stability point) with respect to the overall population (6000 agents) with the chosen Personal Ad. Effectiveness value in comparison to other less likely configurations.

Table 15. Personal ad. effectiveness and resulting equilibria.

Personal Ad. Effectiveness	Personal Ad. Rate	% of portal users among total population (diffusion model stability)
40%	1/7	70%
30%	1/7	67%
20% (2x overall ad campaign)	1/7	63%
10%	1/7	54.5%

The following figures show a comparison of the point distribution if we do not consider a weekly competition effect in the model, and the distribution if such an effect is modelled with a personal ad effectiveness of 20% and personal ad rate of 1/7. Through the weekly e-mails, the dynamics of the activity of users change significantly (see Figure 22). While in the simulation without the weekly stimulus, the number of active users is fluctuating at a relatively low level of 800 active users per week (~13%), the activity in the simulation with the personal weekly ad. increases continuously over the weeks, reaching twice the number of active users after the 12 months. While still many other factors need to be considered, the simulation of the weekly personal ad still indicates that a positive effect of such an incentive strategy on user activity is to be expected.

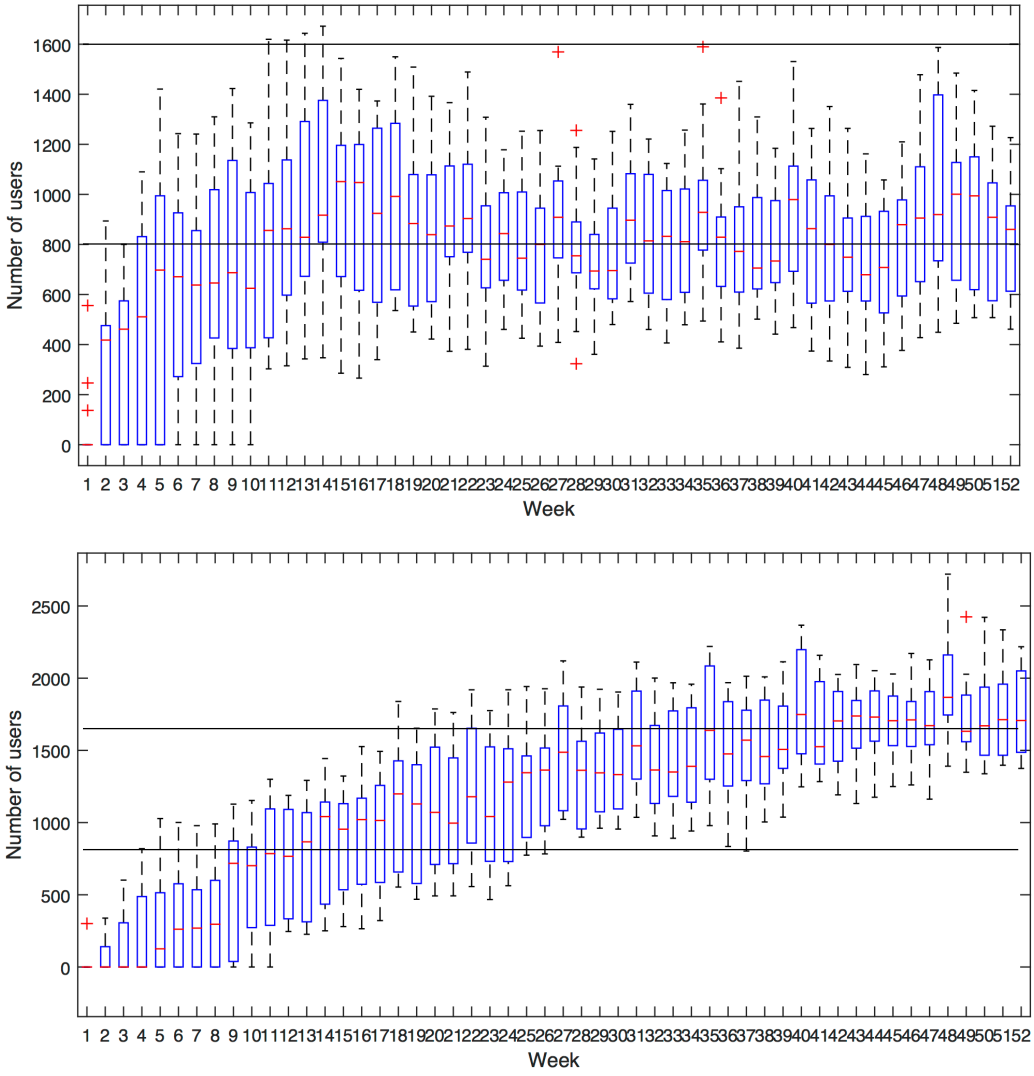


Figure 22. Average number of weekly active users without (above) and with personal ad. effect of weekly competition announcements (below).

The personal ad. effect on users' total point score after the six months simulation is subtler (Figure 23). While the number of users in the lowest point interval (0-5000p) seemingly doubled after the personal ad. effect simulation, one can observe a small overall increase in the number of users who reached higher scores of 100'000 points and more. This trend becomes more obvious in the 12 month simulation, where the distribution of users has shifted visibly in favour of higher point scores (Figure 24). At the same time, there is less of a difference of users in the lowest point interval between the simulation with and without the personal ad. effect, as compared to the simulation after 6 months.

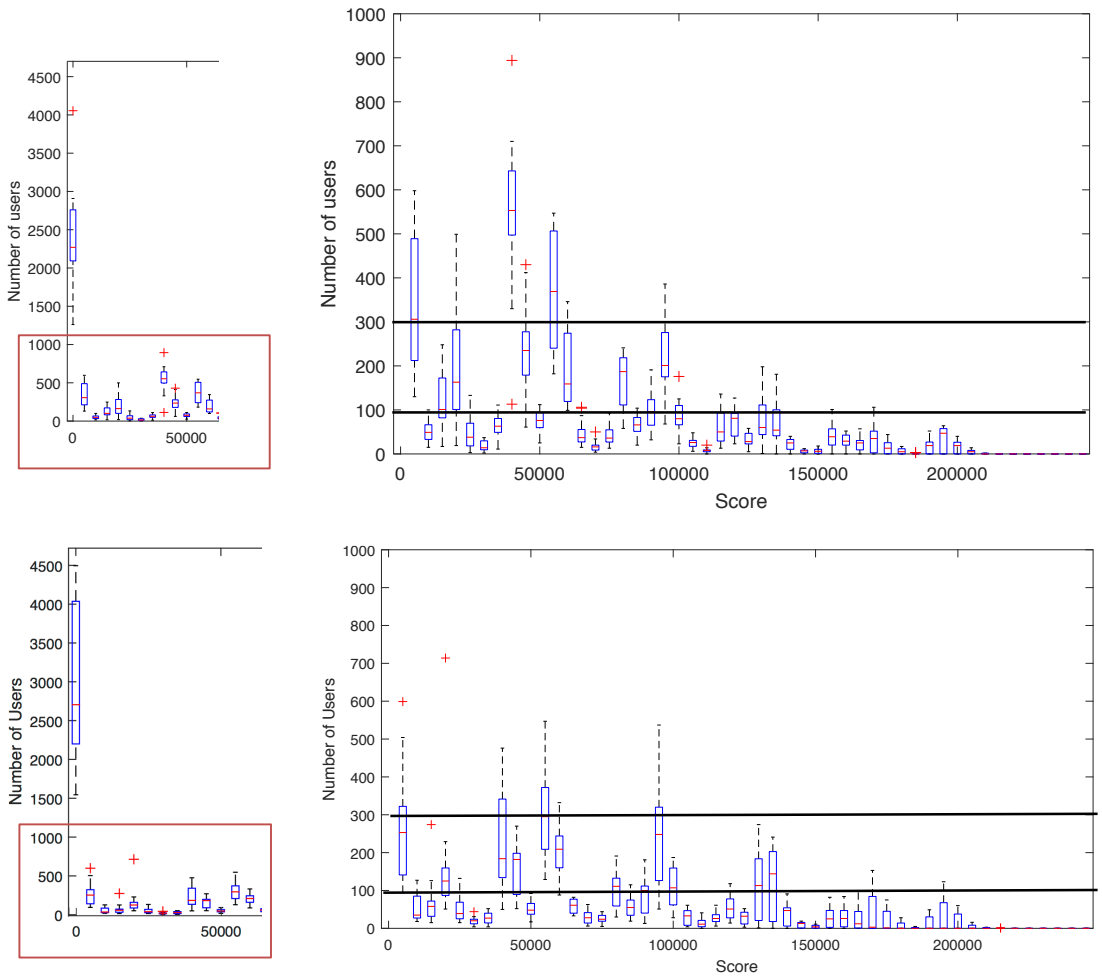


Figure 23. Point distribution after 6m without (above) and with personal ad. effect of weekly competition announcements (below).

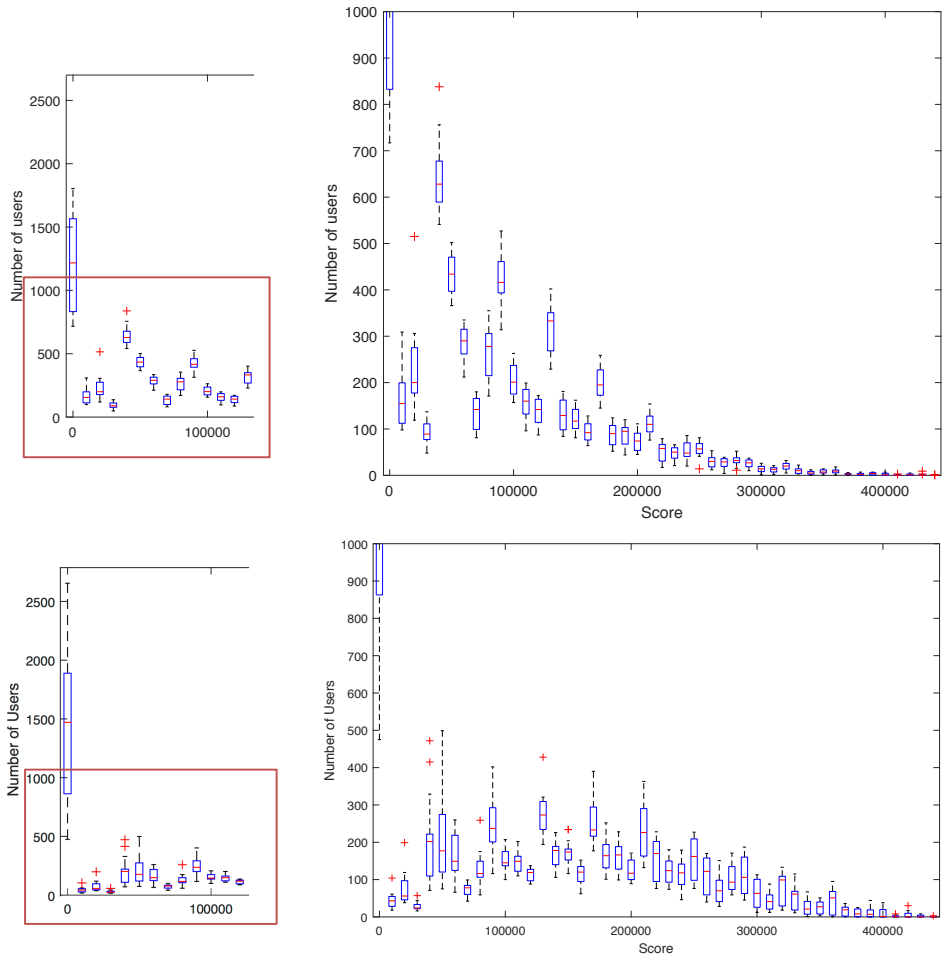


Figure 24. Point distribution after 12m without (above) and with personal ad. effect of weekly competition announcements (below).

5.2 Survey response to badge incentive

In cooperation with WP5, the results of the pricing survey (conducted in Ticino among SES customers) were also used to assess different types of incentive responses.

The full results of the survey and statistical testing of observed differences will be discussed in D5.4[4]. Here, we only report on specific aspects relevant to work on the incentive model in WP4.

In the survey, two incentive measures were tested (Environmental badge vs. bill increase) in two different external scenarios with respect to water availability/shortage (regular conditions vs. water scarcity conditions) (see Table 16). Respondents were asked whether they would alter specific consumption habits under the conditions described in the scenario. In this deliverable we focus on the incentive response rather than the water availability conditions.

A control group was also established which wasn't offered any incentive.

[4] D5.4 due M30

Table 16. Questionnaire versions by incentive measures & water scarcity scenarios (see D5.4 for details).

Incentives	#Respondents	
	#	%
Badge°	**150** (82 regular / 68 scarcity)	**32,47** (17,75 regular / 14,72 scarcity)
Bill increase^	**168** (86 regular / 82 scarcity)	**36,36** (18,61 regular / 17,75 scarcity)
Control	**65**	**14.07**
Scarcity*	79	17.10
Total	**462**	**100.00**

° Users who undertake water saving actions are rewarded with a "Best friend of environment" badge that is advertised in the town;

^ Users who do not undertake water saving actions have the semester water bill increased by 40CHF/semester-household (23.3-43.5% of the reference bill range);

*The district is facing a severe water supply issue/water shortage

The results of the survey indicate that the environmental badge that is advertised in the town promises to be an incentive as effective as bill increase, e.g. for shower time reduction, garden irrigation time reduction or moving washing to night. Some questions even indicate that it may be significantly more effective for certain activities, e.g. switching from baths to showers, balcony or houseplant watering reduction, or most significantly, better swimming pool management (see Figure 25). This preliminarily confirms the incentive scheme applied in the SmartH2Oportal, as users can earn different virtual badges and showcase them in the public leaderboard. This may have similar effects on their behaviour as the stated expected behaviour of the environmental badge in the survey.

Figure 25. Survey responses on willingness to change behaviour in specific scenario.

5.3 Visualization and hedonic design as incentives

In the Swiss case study, the SmartH2Oportal was introduced in a sequence of frequent consecutive releases that were synchronized with the development of the main portal features. During the first months, only the basic portal was available to users, and user activity was not yet logged. Therefore, to conclude the initial basic portal trial in the Swiss case study, a first questionnaire was distributed via e-mail to all users. Among other aspects, feedback on consumption visualization and hedonic design as incentive strategies to make water saving more relevant in users' lives was collected.

At the time of the evaluation, 40 users were registered on the basic portal, and 15 users (incl. 5 alpha users) responded over the 3 weeks during which the questionnaire was available (return rate = 37,5%). For more details and results, see D7.2.

Responses indicate that already the consumption chart and overview widget with basic traffic-light-like indicators have a positive incentive effect in the sense that they made users think about their water consumption more often than before (see Figure 26).

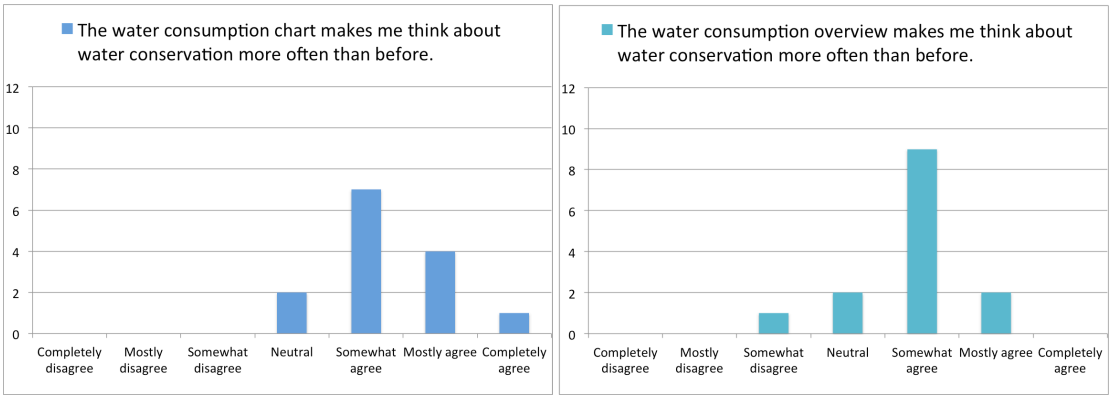


Figure 26. Water consumption visualization as incentive.

A portion of users also stated that they found using the system was fun, and most that it made water conservation more interesting (see Figure 27), both indicators that even a basic portal that has no explicit gamification features can act as an incentive to at least think about water in a different way.

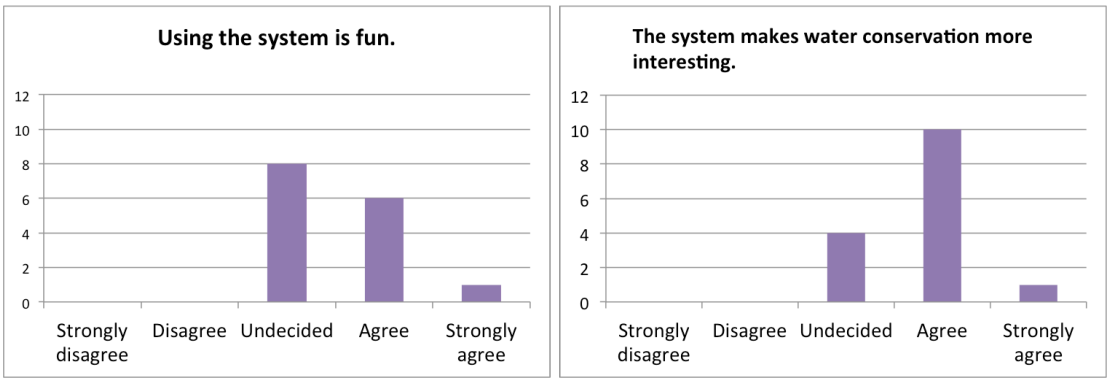


Figure 27. Hedonic design as incentive.

5.4 Log analysis of the Gamified Portal

To understand the user activity that has been logged after the deployment of the gamified portal in the Swiss case study, one needs to consider the specific case study characteristics and main goals. As we had already learned during the requirements phase (see D2.2), the local population in the Swiss case study area can be described as rather pragmatic and hesitant towards new technolgy, living in a relatively rural and conservative area. In addition, the population of households with smart water meters is very small, which makes it the ideal small-scale pilot testing environment for the SmartH2Oproject. Main objectives have been to test the SmartH2Osmart metering infrastructure in real-world conditions, including the data transfer between the meters and the web portal, and fix all technical bugs before introducing the portal in Valencia, a much larger setting. Because of this, only small-scale advertisement and user recruitment campaigns for the SmartH2Oportal have been initialized so far, and especially in the early deployment phase, the focus was to familiarize only a core group of users with the portal and gain some basic understanding of the portal and incentive dynamics rather than aiming for a large active user base.

For the upcoming months, more advertisement campaigns are planned to stimulate participation of existing portal users and to gain some additional users. However, considering the population size and characteristics, as well as experience from similar web portals, the

number of total users is expected to remain relatively small, and even more so the number of active users.

From November 2015, user activity in the CH case study was logged (joint release with basic portal V2 on October 26, 2015). As per February 2016, there were 27 basic users and 16 users of the gamified portal. In this section we focus on the activity of gamified portal users as a first analysis of the SmartH2Oincentive model.

Figure 28 shows the number of daily logins over the monitored period. The login rate until the release of the gamified portal was relatively low, and because the launch of the new version wasn't officially communicated right way to existing users, there was also no increase in activity in the first weeks after the launch. However, an advertisement campaign in the form of a Christmas card resulted in a much higher activity, which is a promising result with respect to the effect of the planned weekly competition winner announcement e-mails in Valencia, indicating the positive effect of such targeted campaigns that had already been observed in the simulation (see 5.1.3).

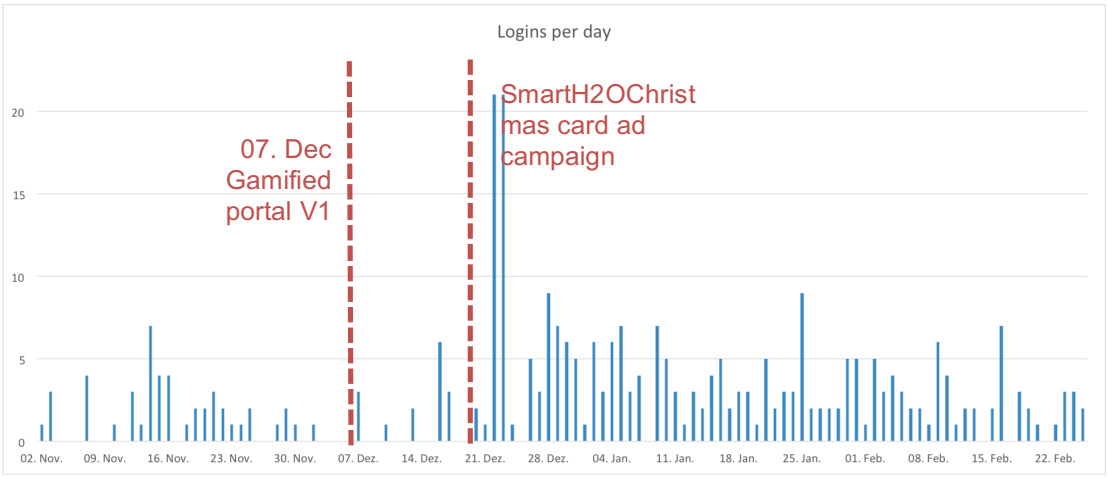


Figure 28. No. of daily logins.

Figure 29 shows the number of gamified portal users who accessed the main portal pages more than just once. While it was to be expected that the consumption page was visited more than once by most users (14 of 16) since it is the default page, Figure 30 shows that more than half the users also interacted with the water consumption chart. In addition, half the users re-visited the consumption overview page visualizing the current consumption using a water pipe metaphor. Figure 29 also shows that more than half the users visited the profile page and not only did those users visit the profile page – 8 of the 16 users filled out 100% of their profile, and an additional 3 filled it out at least partially (see Figure 31).

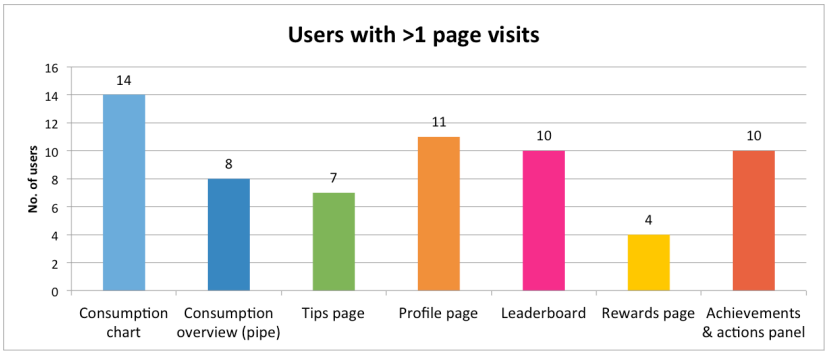


Figure 29. No. of gamified portal users with >1 page visits for the main portal pages.

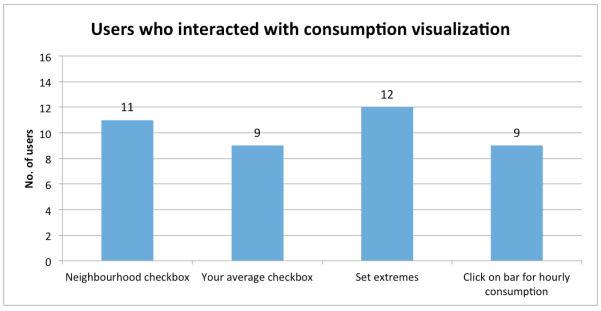


Figure 30. No. of gamified portal users who interacted with consumption chart.

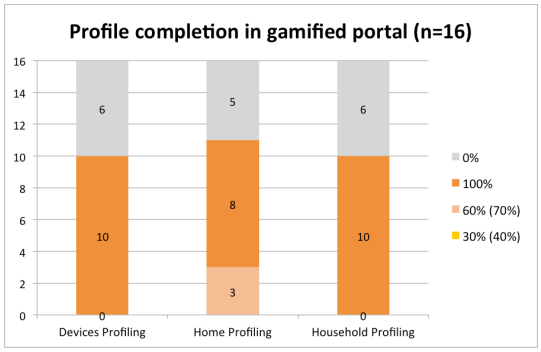


Figure 31. Profile completion percentage of gamified portal users.

Both the leaderboard page and the gamification panel ("right panel") were among the most popular elements for most users (see Figure 29), indicating that these main gamification elements were recognized as such. Looking at the badges won by individual users (Figure 32) one can observe that 13 users earned at least one badge, out of which 11 users earned badges that required additional user interaction (Water saving badges can only be reached by saving water). The first two profiling badges were actually earned by two thirds of the gamified portal users (see Figure 34), and half the users earned the first water saving badge. The water consumption badge is only a first indicator of users' actual water consumption reduction, and does not reflect seasonal differences. For a detailed discussion of users' water consumption reduction, see *D7.2 Validation report*.

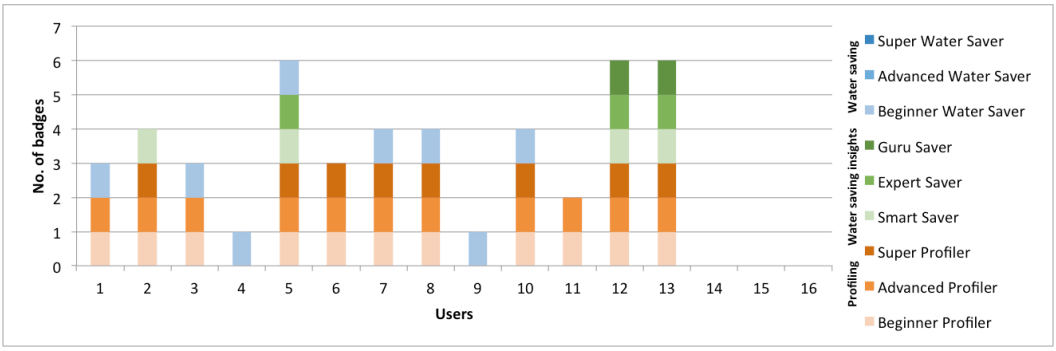


Figure 32. No. of badges won by gamified portal users.

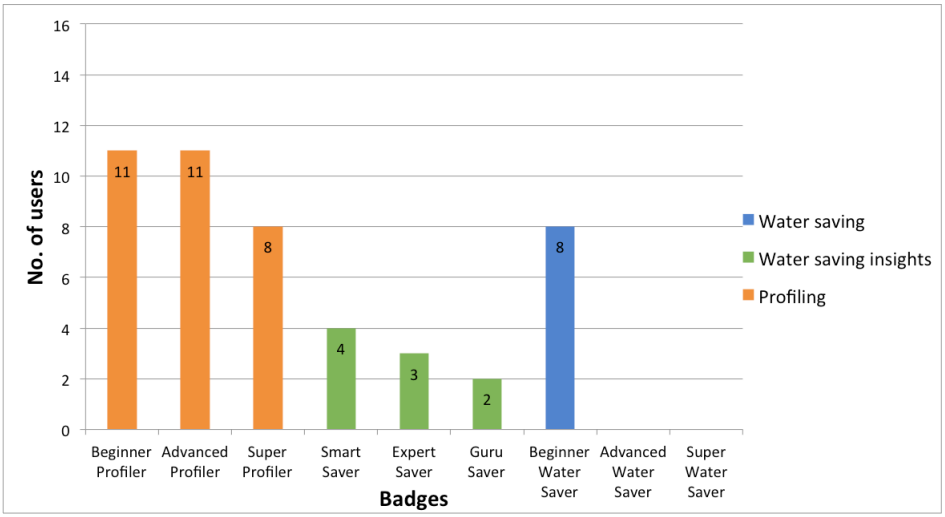


Figure 33. No. of users who achieved each badge.

Figure 34 shows the number of points earned by users on the gamified portal. 11 of the 16 users have earned at least 10000 points, and 7 users have had enough points to claim rewards other than Drop!, which in the CH case study was available to all users who at least signed in once (see 4.2.2 for details on what rewards are available in CH). However, only 2 users actually claimed any type of reward, which could indicate that external rewards are not driving the users' activity, or that most users are saving up their points to be able to claim more valuable rewards later.

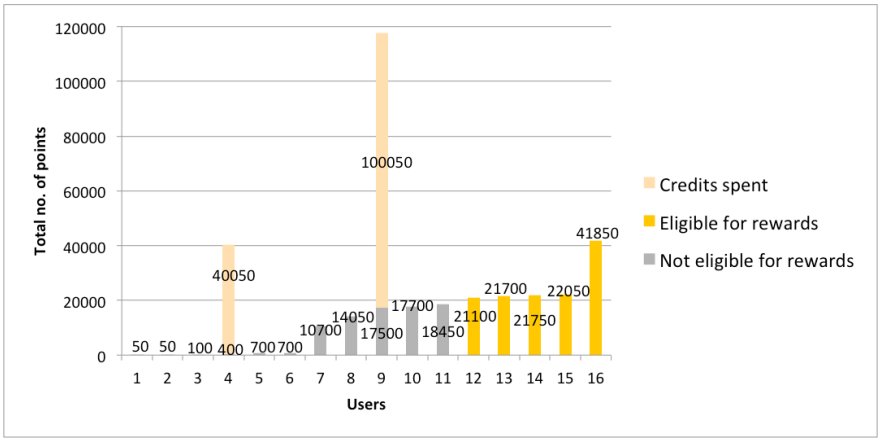


Figure 34. No. of points earned by gamified portal users.

Both Figure 32 and Figure 34 show that there are currently 3 lead users with a high activity rate and high point scores on the portal. The percentage of lead users in comparison to the total size of the user base (7,14% of 42 users) seems to be comparable to lead user activity levels one would encounter in similar systems. E.g., Ortega et al. (2008 as cited in [Preece and Shneiderman, 2009]) found that fewer than 10% of users contributed 90% of online comments in the system they studied.

To better understand the actions and possible motivators of those lead users, we consider them separately (Table 17). Two of the users display a similar weekly login rate, while the third user stands out to the extreme that s/he has on average logged in 17,6 times per week. Out of the three users, two have claimed rewards, while the 3rd user has collected sufficient points to claim any available reward but not used them yet. All three users have collected 6 badges each, although only one of them (LU1) has currently earned a water saving badge.

Table 17. Lead user (LU) activity.

	LU 1	LU 2	LU 3
Logins total	39	176	21
Average logins p. week	2,6	17,6	2,33
Earnings on the portal			
Points total	41850	17500	400
Points spent	0	40050	100050
No. Of Badges	6	6	6
Rewards claimed	–	3	2
Main portal elements usage			
Profile page visits	31	51	20
Tips page visits	23	94	45
Leaderboard visits	61	147	49
Gamification panel	41	26	26
Reward page visits	3	22	10
Consumption visualization usage			
Consumption chart visits	41 (+39 logins)	79 (+176 logins)	69 (+21 logins)
Consumption overview visits	2	65	28
Interactions w/ consumption chart	5	122	29
Your average checkbox toggle	23	73	1
Neighbourhood average toggle	24	68	17

Figure 35 shows how often the lead users viewed or interacted with each main portal element per login (i.e. per session). It shows e.g. that LU3 was especially interested in their consumption and visited both the consumption chart (portal home page) and the overview tab more than twice as often as the other two users in relation to total logins. LU3 also frequented the leaderboard the most per login, and viewed the gamification panel more than once per login. He was also visiting the tips page four times as often as the others per login. While LU2 was by far the most active in terms of total interactions, he was mainly checking the leaderboard and the consumption chart during his visits, but e.g. paid little attention to the gamification panel, especially in comparison to the other two lead users.

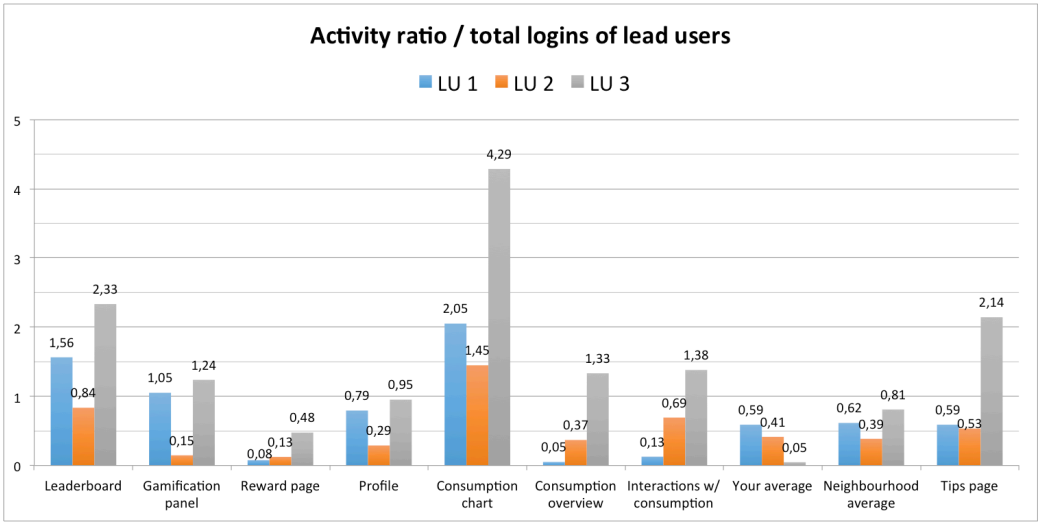


Figure 35. Lead user interaction with main portal elements per login.

Figure 36, Figure 37 and Figure 38 show that while all three users continuously used the portal over a certain time period, they perceived the virtual and tangible rewards very differently, showcasing three different types of incentive response.

While LU1 (Figure 36) continuously earned badges, he never claimed an external reward despite his ability to do so (current score = 41850 points). The fact that he frequented the leaderboard regularly could indicate that for him, it was more important to keep the points and rank high on the leaderboard (compare total point score with ranking in Figure 34), rather than get a real reward.

LU2 (Figure 37) earned all his badges within a very short time, and after a short period of power portal usage, claimed the available rewards all at once and only shortly after earning the necessary points. Yet he continued to login frequently and view his consumption chart, also checking his status on the leaderboard during most visits.

LU3 (Figure 38) earned his badges all within a very short time, too, but continued to frequent the portal at a moderate pace until he reached enough points to redeem the main reward (Amphiro). Shortly after claiming the reward, he stopped using the portal, which could indicate that his portal usage was mainly driven by the one most valuable external reward.

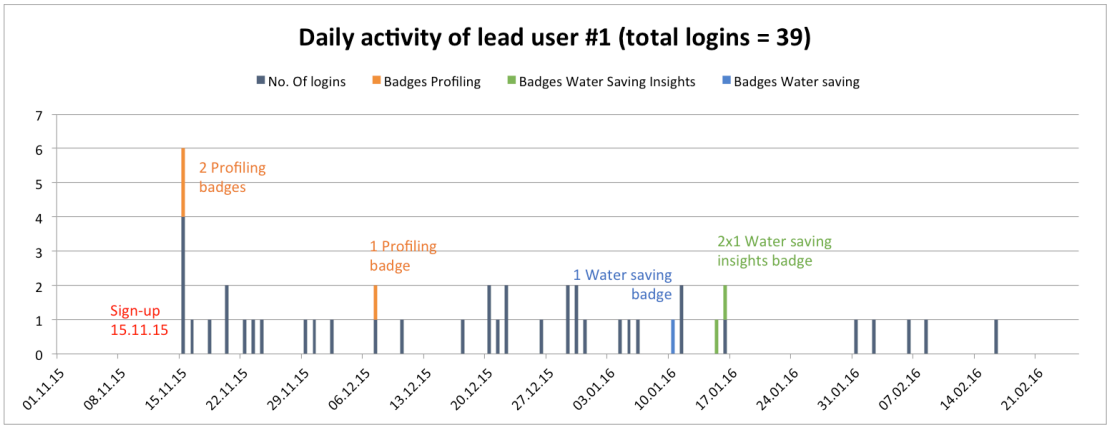


Figure 36. Activity of LU1.

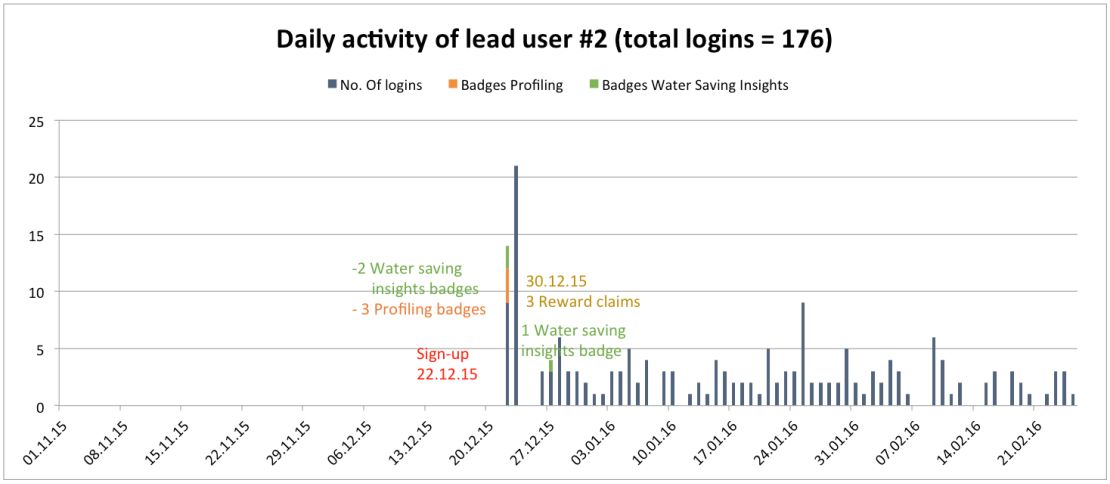


Figure 37. Activity of LU2.

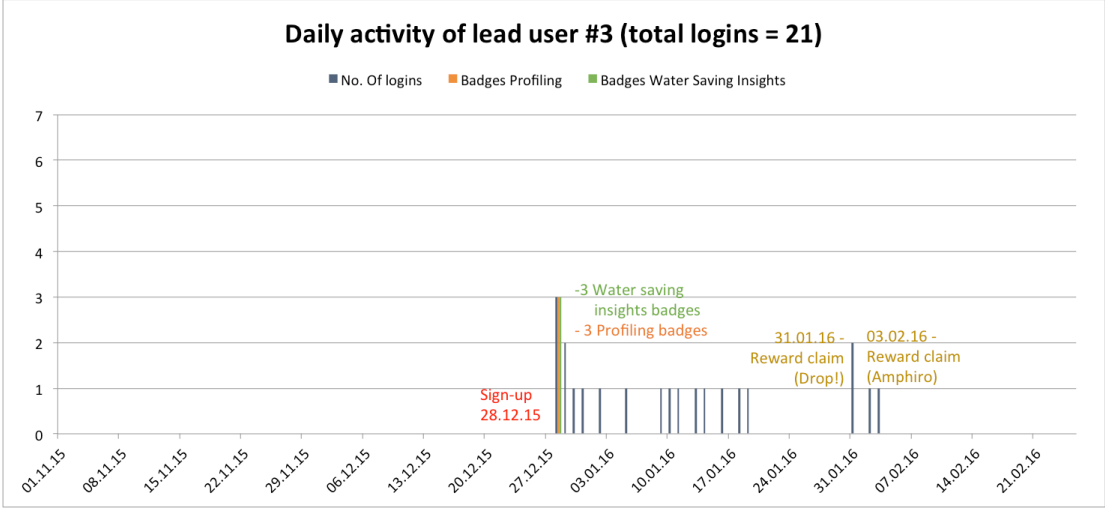


Figure 38. Activity of LU3.

Summarizing, the above analysis indicates that while being able to view one's water consumption can be considered an incentive to use the portal in itself, additional incentives are needed to keep more users continuously interested in the portal. Especially the analysis of the lead user activity showcases how users interact differently with the portal, depending on their motivation and interests. Looking at the overall logs, especially the leaderboard seems to attract more than half the users in the Swiss case study. Interactive features with which users can e.g. take a closer look at their consumption, or even just provide more details about their household in exchange for points have also been tried out by many users and are likely to add to the appeal of the portal. Since not many users have claimed external rewards, additional feedback needs to be collected to learn more about user motivation with respect to external vs. virtual rewards like badges, which have been earned by most users. However, even if external rewards are claimed, the analysis of the lead users has shown that such rewards do not have to be the sole drivers of their portal usage.

And especially the positive reactions to the Christmas communication campaign show that additional triggers and targeted advertisement campaigns do stimulate user behaviour.

Now that we understand the dynamics of the system better, including possible effects of the applied incentives, we will initiate additional targeted communication and incentive strategies to further postulate the usage of the system.

The first meausure will be to establish weekly e-mails as an additional participation incentive and reminder, similar to what is planned in Valencia. As the reward strategy in Switzerland does not foresee competitions, the content of the e-mails could be a kind of weekly digest and call for participation. And, especially when additional social features have been introduced in the next release, social dynamics can be analysed further, also e.g. by highlighting the role of the leaderboard a bit more to stimulate competitiveness and social comparison among users.

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