D 5.2 INCENTIVES AND ENGAGEMENT STRATEGIES

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EXECUTIVE SUMMARY

This deliverable presents the motivational models and incentives used in behavioural change and persuasive systems for sustainability applications. The deliverable is specified in the enCOMPASS Description of Action as follows: *"a review of motivational models in games and persuasive applications; survey of incentive models and algorithms; review of specific incentives used in sustainability challenges; recommendation of incentive models and algorithms appropriate for enCOMPASS."*

The deliverable is organized as follows:

- Section 1 introduces the content of the deliverable.
- Section 2 presents the essential principles of motivation theory, the discipline at the base of persuasive system design; in particular, it distinguishes among needs-based, social-based, and reward-based motivation factors. It also summarizes the links between Motivation Theory and Goal Setting Theory.
- Section 3 translates motivation theory principles into design principles for behaviour change systems, focusing on the principal models of user behaviour and persuasive systems design.
- Section 4 puts motivation theory and persuasive system design results in the context of the development of digital systems in which humans and computers collaborate to the fulfillment of a task or to the achievement of a goal (e.g., energy saving). This emerging research field is called Human Computation (Quinn 11) and comprises the two special classes of persuasive systems called gamified applications and games with a purpose (GWAPs), which are closely related to the design approach of enCOMPASS. The section concludes with the presentation of an abstract generic incentive delivery algorithm, which generalizes the approaches surveyed in the section.
- Section 5 details the specific engagement and incentive stimuli (actions and corresponding symbolic of physical rewards) that can be used to instantiate the generic incentive algorithms for sustainability challenges, as found in the various classes of systems reviewed in the preceding sections; these classes of actions and rewards form the basis for the design of enCOMPASS.
- Section 6 draws the conclusions and highlights the incentive elements and design principles that will be adopted in enCOMPASS.

The analysis of the incentive models and applications in this deliverable together with the findings from *D5.1 Behavioural change models and determinants for energy consumption* provides a sound theoretical basis that informs and complements the user-centered requirements analysis and specification for the enCOMPASS system performed in WP2. This is correlated with the other deliverables and tasks as follows:

- Most of the design recommendations and principles identified in this deliverable have already been used as input and integrated into the requirements analysis and specification process (see *D2.1 Use cases and early requirements*).
- The identified design recommendations and principles will be addressed in more detail in the second requirements iteration (producing D2.2 Final requirements, M12)
- The tasks where specific solutions and elements of the enCOMPASS system are being developed (e.g. T 5.2 Energy consumption visualization and feedback, T 5.3 Adaptive gamification for behaviour change, T 5.4 Hybrid digital-physical energy games for behaviour change) will also be influenced by the analysis done in this deliverable.

In addition to such an “internal” value for the enCOMPASS project, this deliverable also presents a valuable resource for informing other researchers investigating and designing behavioural change systems in the energy saving domain.

1 INTRODUCTION

enCOMPASS develops a sociotechnical system that seeks to induce a change in energy consumption behaviour through a mix of incentives. Often these systems are referred to as persuasive systems (Fogg, 1998), or behavioural change support systems (Oinas-Kukkonen, 2013).

This deliverable describes the main motivational models and theories relevant for the design of the enCOMPASS project (Section 2), including goal framing and attention triggering which have been underinvestigated in the design of behavioural change applications in the energy domain so far. The main models from the persuasive system design are presented and discussed in terms of their relevance for the design of the enCOMPASS system (Section 3). An entire chapter (section 4) is devoted to mapping out different types of gamified applications that can inform the development of the enCOMPASS gamification model, including their underlying design principles and player types. In this context, a set of selected application examples from the water and energy saving domain are also described, for better illustrating the different types of approaches relevant for enCOMPASS. This survey is extended with a review of different types of incentives applied in different classes of behavioural change approaches for sustainability challenges, both from the academic and non-academic world (section 5).

The deliverable concludes (Section 6) with a synthesis of main recommendations of incentive elements for the design of the enCOMPASS incentive end-user applications. These include specific incentive elements and design suggestions for:

- Raising user awareness by enabling them to explore and understand their energy consumption;
- Promoting commitment by stimulating users to target specific energy consumption goals;
- Increasing motivation and continuous engagement with gamified virtual, social and physical rewards;
- Strengthening norms with consumption reminders and normative symbols;
- Increasing behavioural control with actionable tips;
- Continuously triggering user attention through push notifications;
- Engaging uses through through a hybrid digital-physical card game.

2 MOTIVATIONAL MODELS

In this section and in Section 3 the theoretical foundation for persuasive systems is provided. This section highlights the importance of motivation for the enCOMPASS applications to induce behavioural change. We review different motivational theories that explain the abstract drivers of human behaviour. We then zoom in on the situation-dependent goals of the user. In Section 3 we will focus on ICT-mediated behavioural change incentives, by addressing different models of persuasive system design.

2.1 MOTIVATIONAL THEORY

For any behavioural change to happen, one must be capable, one must have the opportunity to do so, and one must be motivated (Michie et al., 2011). Motivation is particularly important for behavioural change in energy saving behaviour. In general, consequences of energy saving actions are not immediately visible to the consumers due to the low frequency of energy billing, the invisibility of consumed energy and the relatively abstract unit in which it is measured (kWh), and the positive environmental impact resulting from energy saving is achieved out of sight of the consumer. Additionally, while in households the financial incentive to save energy is quite strong as cost per kWh is relatively high, in other contexts where the consumer is not responsible for the energy bill, this incentive falls short (e.g. in schools or public buildings, the other two key contexts for the enCOMPASS project). As a consequence, energy consumers need a strong motivation to engage in energy saving actions, both at home, in the workplace or at school.

However, as noted in *D5.1 Behavioural Change models and Determinants for Energy Consumption*, the behavioural change models based on the Theory of Planned Behaviour (Ajzen, 1991) as well as process models (e.g. Bamberg, 2003; Prochaska & Velicer, 1997) underestimate the importance of motivation for behavioural change. Therefore, in this sub section we provide a succinct overview of motivational theory. Motivation may be defined as the 'energization' (i.e., instigation) and direction of behaviour (Elliott & Covington, 2001, p. 73). It represents the reasons for people's actions, desires, and needs. The motivation of users to engage in energy saving actions is a critical success factor for a behavioural change system. The vast amount of research on human motivation has yielded several influential theories whose key notions must be introduced into the behavioural change process model for energy consumption behaviour. The following subsections thus give an overview over the key motivational theories.

2.1.1 Motivational theories and affordances

Vassileva (2012) has proposed a model for motivation in social computing applications that can inform incentive modelling for behavioural change. Three classes of motivational theories are distinguished: needs-based, social-based, and rewards-based theories of human motivation. The following subsections outline the motivational theories in each of these classes. The reviewed motivational theories are increasingly applied to improve engagement with ICT-systems, reflecting the growing attention in research for motivational aspects of system use. This has led to the emergence of the concept of motivational affordances, as properties of an object that determine whether and how it can support one's motivational needs (Zhang, 2008). The more a system appeals to these needs, the stronger the drive users feel to use it. Accordingly, behavioural change systems need to offer different types (and combinations) of need-based, social-based, or reward-based motivational affordances to engage users.

2.1.2 Needs-based motivation

There are different main needs-based motivation theories: the need achievement theory, goal setting theory, self-efficacy theory and basic desires theory. Each is shortly described in the following paragraphs.

Need Achievement Theory states that achieving success and avoiding failure are separate motives that guide human behaviour. This way, humans demonstrate to themselves or to others high rather than low ability (Atkinson, 1960). People highly motivated to succeed prefer tasks of intermediate difficulty. People highly motivated to avoid failure on the other hand tend to prefer either very simple or very difficult tasks (Atkinson, 1960; Richter et al., 2015).

Self-efficacy Theory (Bandura, 1977) focuses on the individual's belief in his/her ability to succeed in specific situations. Self-efficacy 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).

Basic Desires Theory identifies sixteen basic desires that guide a large part of human behaviour (Reiss, 2002). Reiss (2002) states that these desires motivate people's actions and define their personalities. The desires are the need for approval, learning, food, raising children, loyalty to traditional values, social justice, independence, organized environments, physical activity, power, romance saving and collecting, social contact, social status, safety, and competition.

2.1.3 Social-based motivation

The two main social-based motivation theories are highlighted below.

Social Comparison Theory is built on the assumption that people are driven by their need for accurate self-evaluations of their opinions and abilities. First, objective evaluations are sought, but when unavailable, people resort to compare their opinions and abilities against others (Festinger, 1954). Suls & Martin (2000) point out the factors that influence an individual's use of social comparison: the other person's expertise, similarity with the individual, and previous agreement with the individual. For the incentive model the motivational effect of social comparison for self-enhancement and keeping a positive self-evaluation are particularly relevant.

Personal Investment Theory (Schilling & Hayashi, 2001) suggests that an individual's investment of time and effort in a task depends on personal incentives, self-beliefs, and available alternatives (Richter et al., 2015). Three basic components determine one's personal investment: personal incentives, sense of self, and perceived options (Schilling & Hayashi, 2001; Richter et al., 2015). The personal incentives can contain task incentives (e.g. skill improvement), ego incentives (e.g. wish to outperform others), social incentives (e.g. affiliation with others), or extrinsic rewards (e.g. monetary compensation, social recognition, approval). The sense of self refers to perceptions, beliefs and feelings related to competence, goal-directedness, self-reliance and social identity. Last, perceived options are available and appropriate alternative choices, often influenced by social aspects (Richter et al., 2015).

2.1.4 Reward-based motivation

Among others, there are also two key reward-based motivation theories, which are described here.

Atkinson (1960) has developed the *Expectancy-value Theory* to understand the motivation of users for task achievements, where achievement is determined by an individual's expectations and the subjective value the individual assigns to the task. Expectancies are specific beliefs individuals have regarding their success on certain tasks they will carry out in the short-term future or long-term future (Wigfield & Eccles, 2000). Subjective task values refer to the motivation of an individual to engage in a certain activity (Wigfield & Cambria, 2010). Eccles et al. (1983) defined different components of subjective task 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. 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 & Eccles, 2000).

And finally, according to Skinner's *Reinforcement Theory* (1957), an 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.

2.1.5 Self-Determination theory

Richter et al. (2015) position Self-Determination Theory (SDT) as a comprehensive theory that bridges the aforementioned classes. SDT focuses on types of motivation and asserts that motivation is multidimensional and spans a continuum ranging from intrinsic to extrinsic motivation, to the state of lacking the intention to act (Richter et al., 2015). In this way, extrinsic motivation refers to performing a task in order to attain some separable outcome, whereas intrinsic motivation refers to performing an activity for the inherent satisfaction of the activity itself (Ryan & Deci, 2000).

Self-Determination Theory (SDT) bridges the aforementioned classes (Richter et al., 2015). It represents a broad framework for the study of human motivation and personality, articulating a meta-theory for motivational studies, a formal theory that defines intrinsic and extrinsic sources of motivation, and a description of their roles in cognitive and social development and individual differences. Every individual has been born with the capability to be intrinsically motivated. However, research has shown that supporting conditions are needed to maintain intrinsic motivation (Ryan & Deci, 2000). They argue that over the course of one's childhood activities are increasingly extrinsically motivated, as children have to do activities they do not find interesting per se, but are expected from them.

SDT postulates that that human behaviour is driven by three innate psychological needs: the need for autonomy, the need for competence, and the need for relatedness (Ryan & Deci, 2000; Richter et al., 2015). Autonomy refers to one's control over one's own actions. Competence refers to control the outcome and experience mastery, while relatedness reflects the universal need to interact with and be connected to others. (Ryan & Deci, 2000).

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 (Richter et al., 2015). In contrary, when these needs thwarted, this lead to diminished motivation and well-being (Ryan and Deci, 2000b). 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.

Ryan & Deci perceive motivation as a multidimensional construct that resides along a continuum of self-determination ranging from intrinsic motivation, through extrinsic motivation to amotivation (Ryan & Deci, 2000), the state of lacking the intention to act. On a scale from amotivation to intrinsic motivation, different regulation styles can be employed: non-regulation, external regulation, introjected regulation, identified regulation, and integrated regulation, and finally intrinsic regulation. People experience an increasing level of autonomy. *Externally regulated* behaviour is performed to satisfy an external demand or

reward contingency. Individuals typically experience this behaviour as controlled or alienated. *Introjected regulation* involves taking in a regulation but not fully accepting it as one's own. *Identification* reflects a conscious valuing of a behavioural goal or regulation, such that the action is accepted or owned as something that is personally important. *Integration* occurs when identified regulations are fully assimilated to the self. That is, the behaviour has become congruent with one's other values and needs. The more behaviour is self-regulated, the more autonomy one perceives, and the more intrinsically motivated one is.

2.2 USER GOALS

While motivational theories as abstract drivers of human behaviour help to understand the high-level reasons for e.g. using persuasive systems, the goals of a user in relation to a specific application within a specific context of use must also be considered. Different theoretical notions can support this understanding. In this sub section we will review goals from two different perspectives: **goals** that guide (pro-)**environmental behaviour**, **uses and gratifications** of mobile application and mobile game usage.

Goals in context of pro-environmental behaviour

Goal Setting Theory claims that difficult, specific, context-appropriate, and immediate rather than long-term goals are drivers of high achievements (Ling et al., 2005). A goal is perceived as what the individual is trying to accomplish by directing attention, assembling effort, increasing persistence and belief in ability to complete a task. Efficient goals are proximate in time, moderately difficult, and specific, with an objective definition that is understandable for the individual (Locke et al., 1981). Goal-setting theory implies a rational choice approach, in which behaviour is guided by conscious decisions about what a single goal one wants to achieve and how this can be done. However, in the context of pro-environmental behaviour, goals can drive behaviour that do not meet the criteria postulated by Locke et al. (1981). Instead, multiple overarching goals are can be active at the same time that are potentially in conflict with each other.

According to Goal Framing Theory, such goals are simultaneously present in any given situation, while one goal is more in focus than others. Research has shown that these goals will vary across situations (e.g. Steg et al., 2016). The focal goal influences the way people process information and act upon it (Lindenberg & Steg, 2007). A goal frame is a focal goal together with its framing effects (i.e., its effects on cognitive processes, such as selective attention). Three different goal frames are distinguished: the hedonic goal “to feel better right now,” the gain goal “to guard and improve one’s resources,” and the normative goal “to act appropriately.” (Lindenberg & Steg, 2007, p. 119). When an individual has short-term hedonic goals in focus, s/he is particularly sensitive to what increases or decreases pleasure, or affects one’s mood. In contrast, focal gain goals make people sensitive to changes in personal resources (e.g. money). Finally, the question about what one ought to do, is key for people who have a normative goal frame in focus. Note that all three goal frames are likely to be active at the same time, while in different situations different goal frames can get the upper hand. The likelihood that a pro-environmental choice is made increases if the other goal frames are in line with the focal goal (Steg et al., 2016). The reverse is also true: e.g. a normative goal can be pushed to the background when the hedonic goal becomes focal. This can be the case for example when one thinks about reducing the room temperature. Note that hedonic and gain goals do not necessarily lead to environmentally inefficient behaviour, as e.g. the gain goal to save money on the electricity bill can be compatible with the normative goal of doing the right thing in protecting the environment.

Steg et al. (2016) have identified values and situational factors as the main factors that influence the strength of the normative, gain, and hedonic goal frames. Values are desirable and trans-situational goals that serve as guiding principles in one’s life (Schwartz, 1992 as cited in Van der Werff et al., 2013). Values

reflect which goals people find most important in life in general, whereas goals as defined in goal-framing theory reflect what motivates people in a given particular situation (Steg et al., 2016). Three types of situational factors have been distinguished that each impact the strength of the goal frames and with that the likelihood of pro-environmental behaviour. First, the presence of symbols that have a normative, hedonic or gain connotation can affect the strength of these goals. Second, the behaviour of others can either strengthen or weaken the strength of the goals. For example, when one sees other people littering, the normative goal of acting appropriately weakens, as one sees other people violating this norm. Finally, the perceived costs of pro-environmental behaviour can increase the importance of the gain goal, even in situations in which a strong normative goal frame is present (Steg et al., 2016). In addition to these factors, Miao & Wei (2013) have also shown that different settings impact the importance of normative and hedonic goals. Their study has demonstrated that in households the normative goal is most important, while in a hotel setting, the hedonic goals are most important. Likewise, other environments (e.g. the workplace, or school) may also strengthen or weaken either of the goal frames.

Gölz & Hahnel (2016) have collected partial evidence for the presence of these goal frames in the use of feedback systems. From their study they concluded that in the use of feedback systems users seek to achieve hedonic goals (having fun, avoiding inconvenience due to negative impact of receiving consumption feedback) and gain goals (reducing costs of electricity), but not for normative goals. Instead, learning how to save electricity was found, which does not immediately map on either of Lindenberg & Steg 's (2007) goal frames. However, there is a difference between the learning goal and the other hedonic and gain goals, in the sense that learning how to save electricity can be instrumental to another goal, which may also include e.g. protecting the environment, or doing the right thing, which would then correspond to the normative goal. Alternatively, learning how to save electricity can be perceived as a necessary condition to e.g. save money.

The situational factors also provide opportunities for strategies to be employed in the enCOMPASS user awareness applications. For example, introducing symbols that show approval (e.g. thumbs up) or rejection (e.g. thumbs down) of energy consumption can strengthen the normative goal frame, whereas e.g. showing how easy it is to use a timer on the air conditioning can reduce the perceived costs (e.g. effort) saving energy. The perceived costs will then reduce the emphasis on the gain goal, allowing for the normative goal frame to become more active.

Uses and gratifications of mobile application usage

Uses and gratifications theory originates from research on mass media usage. The basic assumption behind this high-level theory is that the audience (or the users) actively seek out and use media to fulfil their needs. Additionally, it is assumed that different media compete against each other and against other sources of gratification for the attention of the audience (Katz et al, 1974). The uses and gratifications approach has been applied to many different kinds of media and devices (e.g. social media, Raacke & Bonds-Raacke, 2008, mobile phone usage; Leung & Wei, 2000). Across different media and devices, two classes of uses can be distinguished: instrumental uses, which are goal-directed and purposeful, and ritualistic, which are habitual and diversionary (Hiniker et al., 2016).

This distinction closely resembles the distinction between pragmatic and hedonic value users derive from information systems. Utilitarian systems address tasks and activities where user motivation in using the system is driven by the expectation of an external reward or benefit (Heijden, 2004). In contrast, hedonic systems serve activities in which users are intrinsically motivated by benefits stemming from the interaction with the system as such, including fun-of-use (Heijden, 2004). Hedonic systems typically provide stimulation by their challenging or novel character, or identification by communicating important personal values to

others (Hassenzahl, 2004). Utilitarian systems primarily afford instrumental uses, whereas hedonic systems mostly afford ritualistic uses.

As in enCOMPASS gamified applications are developed, the particular (hedonic) uses and gratifications from playing mobile games are particularly relevant. Wei & Lu (2013) found out that enjoyment, interaction with others as individual gratifications, and the perceived number of peers in the social network are strong predictors for playing social games on smartphones. Engl & Nacke (2013) found out that, as a ritualistic use, playing mobile games is primarily an enjoyable way of spending time between daily activities, valued particularly for its ubiquitous availability and its instant entertainment for short time episodes. Mobile gaming is competiting for attention with gratifications gained from other sources, such as reading a book, listening to music, or having a conversation. Thus, in line with uses and gratifications, the authors observe a competition with other media and other non-mediated gratifications.

This sub section has reviewed different goal frames, uses and gratifications, as predictors for pro-environmental behaviour and usage of media respectively. A goal-based approach, combining gratifications from games with the activation of goal frames to encouraging energy efficient behaviour, is a promising research direction to deliver incentive tailored to the needs of different users and user groups. In enCOMPASS this direction is further investigated, by designing a gamified incentive model that appeals users with different motivations for pro-environmental behaviour.

3 PERSUASIVE SYSTEM DESIGN THEORY

In enCOMPASS a sociotechnical system is developed that seeks to induce a change in energy consumption behaviour through a mix of incentives. Often these systems are referred to as persuasive systems (Fogg, 1998), or behavioural change support systems (Oinas-Kukkonen, 2013). Fogg (1998) define persuasive systems as interactive systems designed for attitude and/or behaviour change, which closely resembles the definition of 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). With the focus of persuasive systems on a voluntary change of behaviour, the design of persuasive systems requires a reflection on the underlying psychological processes the systems seeks to influence (Spagnolli et al., 2016). This includes an analysis of the motivational drivers of the user (as discussed in the previous section), and the specific determinants of the behaviour one seeks to change.

The design of the enCOMPASS application is then a challenge of fusing insights from Human Computer Interaction (HCI) research, in terms of both motivational and persuasive design, with insights from behavioural psychology (for an overview, see *D5.1 5Behavioural change models and determinants for energy consumption.* From an HCI perspective, designing for behavioural change is perceived through the lens of the 'affordance' concept, which refers to a perceptual property that hints at a possible usage of the object in a given situation and is immediately or intuitively recognized by instinct or education (Gaver, 1991; Spagnolli et al., 2016; Norman, 1988). In other words, elements in systems can be designed in such a way that they afford a certain behaviour of the user. While this can be perceived as a subtle kind of persuasion, persuasive systems differ from affordance design, in the sense that persuasive systems have the explicit overall design goal of influencing the target behaviour through interaction with the system (Spagnolli et al., 2016).

Even though empirically validated models for the design, development, and validation of such systems are not yet available, the available theoretical models can still support the conceptualisation and validation of the applications in enCOMPASS.

In the rest of this section, we discuss models from Fogg (1998; 2009), and Oinas-Kukkonen (2009; 2013). We then zoom in on an important precondition for behavioural change to happen, which is triggering the attention of the user (Fogg, 2009). Finally, we discuss the effectiveness of behavioural change support systems, as evidence for the approach that was adopted in enCOMPASS.

3.1 FOGG'S BEHAVIOUR MODEL

Fogg (2009) has postulated a persuasive system model whose basic premise is that for a target behaviour to happen, a person must have sufficient **motivation**, sufficient **ability**, and an effective **trigger**. Fogg (2009) claims that the likelihood of behavioural change to happen increases with an increasing motivation and ability. For system designers, this means that there are two options to increase the likelihood of behavioural change to happen: to increase the motivation, and to increase the ability by making the desired behaviour easier. However, a strong motivation and high ability are insufficient. A trigger is needed to set off behavioural change. This happens when three conditions are simultaneously met:

1. The trigger must get noticed by the users;
2. The trigger must be associated to the target behaviour;
3. The trigger must be well-timed, at a moment where both the motivation and the ability is high.

Fogg (2009) introduces the concept of a behavioural activation threshold: the ability level and motivation level must be above this threshold for a trigger to set off the target behaviour. In order to increase user motivation, the design of behavioural change support systems can appeal to different motivations for behavioural change. Fogg (2009) distinguishes:

1. Pleasure / pain
2. Hope / fear
3. Social acceptance / rejection

Furthermore, Fogg (2009) perceive the task of system designers to increase ability as a task ensures simplicity of the system. Simplicity is achieved when the six elements are as limited as possible:

1. Time: the amount of time one needs to invest to perform the target behaviour
2. Money: the amount of money one needs to invest to perform the target behaviour
3. Physical effort: the amount of physical effort required to perform the target behaviour
4. Brain cycles: the amount of thought one needs to invest to perform the target behaviour
5. Social deviance: the extent to which one needs to go against social norms.
6. Non-routine: the extent to which one needs to change existing habits.

Triggers are subdivided into three types:

- A **spark**. When a person lacks motivation to perform a target behaviour, a trigger should be designed in tandem with a motivational element, such as a video that instils hope or fear, or any other of the motivational elements.
- A **facilitator**. A facilitator is appropriate for users that have high motivation but lack ability.
- A **signal**. A signal is used when people have both the ability and the motivation to perform the target behaviour. A signal serves as a reminder to engage in the target behaviour.

The model proposed by Fogg (2009) is summarized in Figure 1.

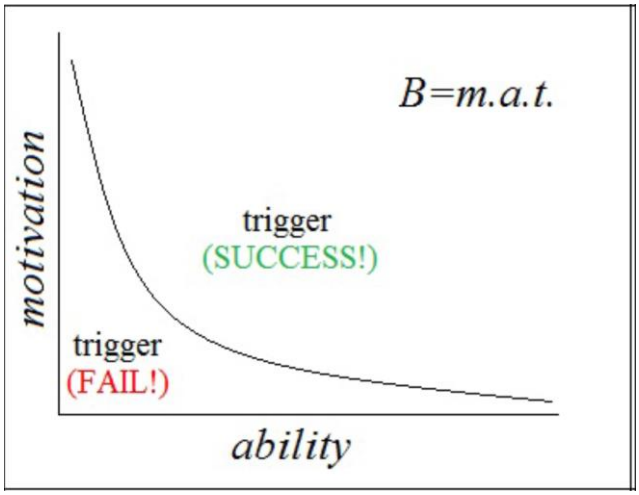

Figure 1: The Fogg Behaviour Model (Fogg, 2009).

Figure 1 demonstrates that low scores on ability (x-axis) and/or motivation (y-axis) are unlikely to induce behavioural change. The trigger factor is can be placed anywhere inside the plane defined by the motivation and ability.

In spite of the frequent usage of this model and its face validity, the model is fairly limited in its validity. First, the work is not grounded in psychological theory about behavioural change. For example, it is unclear which factors contribute to motivation, and ability. The conceptualisation of motivation is rather limited, when compared to the overview of motivational models provided in Section 2. Additionally, a range of other non-motivational factors often found to impact behavioural change are not addressed by this model, such as underlying attitudes, beliefs, personal, social norms, and the habitual nature of many behaviours. Furthermore, the model does not make explicit how the suggested design principles can and should be transformed into software requirements and further implemented as actual system features (Oinas-Kukkonen & Harjumaa, 2009).

In spite of these shortcomings, the importance of triggers as drivers for behavioural change is important for the enCOMPASS context. Energy behaviour can be characterized by a low level of involvement, and attention, while a significant share of the behaviour is driven by habits. In such context, trigger the attention of the users is of key importance.

3.2 OINAS-KUKKONEN'S PSD MODEL

The Persuasive Systems Design (PSD) model (Oinas-Kukkonen, 2013; Oinas-Kukkonen & Harjumaa, 2009) addresses the conceptual design of a behavioural change system in three subsequent steps. As a first step, a set of seven design postulates must be considered. Second, an analysis is required of the persuasion context. Finally, as a last step, the persuasive software features must be modelled.

Design postulates

Oinas-Kukkonen (2013) and Oinas-Kukkonen & Harjumaa (2009) pose seven design postulates common to all BCSS's. The postulates combine insights from user acceptance literature with insights from behavioural psychology.

1. **IT-is never neutral**, as the introduction of an IT system always has some influence on the user. In that sense, persuasion must be considered a process rather than a single event during which e.g. the goals of the user may change. Behavioural change support systems should be able to cope with such changes over time.
2. **Consistency** is needed, as people like their views of the world to be consistent. This postulate indicates potential for behavioural change, as pointing out inconsistencies between e.g. attitudes and behaviour, people are inclined to change their behaviour when the dissonance is large enough.
3. Persuasion is often of an **incremental** rather than radical nature. A BCSS should enable users to make incremental steps towards the target behaviour, while clearly communicating the final goal. Encouraging users to perform small incremental steps is easier than to persuade them to take big steps.
4. Direct and indirect **routes** to persuasion must be employed, in which, following the Elaboration Likelihood Model (Petty & Cacioppo, 1986), users who take the direct route active process the content of the persuasive message, while users who take the indirect route rely on simple cues and heuristics for evaluating the information.
5. **Usefulness** and **ease of use**. The designed system should serve the needs and should meet generic usability and system performance criteria, such as responsiveness, lack of errors, quality of information, visual appeal, ease-of-use, etc.
6. Persuasion through a BCSS must be **unobtrusive** to a user's primary tasks. This postulate implies that an opportune moment should be identified at which the persuasive message can be delivered without disrupting the user's primary tasks.

7. Persuasion must always be **transparent.** This postulate requires to be open about the designer and the assumptions behind the BCSS to avoid losing its trustworthiness and persuasive potential.

Note that these design postulates are not fully specific to the context of a BCSS to a small extent, as postulates 1, 5, 6, and 7 are applicable to any information system, and as such have received substantial attention in the user acceptance and user experience literature (e.g. Seffah et al., 2006; Venkatesh et al., 2012).

The persuasion context

The persuasion context encompasses intent, event, and strategy. In this model the **intent** refers to the specific behavioural outcomes and changes the BCSS intends to achieve. Oinas-Kukkonen (2013) have developed an Outcome/Change matrix containing nine different potential intentions of a BCSS. The matrix is displayed in Table 1.

Table 1: O/C Matrix from Oinas-Kukkonen (2013).

	C[1]-Change	B-Change	A-Change
F-Outcome	Forming an act of complying	Forming a behaviour	Forming an attitude
A-Outcome	Altering an act of complying	Altering a behaviour	Altering an attitude
R-Outcome	Reinforcing an act of complying	Reinforcing a behaviour	Reinforcing an attitude

A forming outcome (F) means the formulation of a new behavioural pattern. An altering outcome (A) means that an existing behavioural response to needs to be changed. The change can be a change in frequency, intensity, or duration of the behaviour. A reinforcing outcome (R) means that existing attitudes or behaviours are strengthened, making them more resilient to change. While quitting a behaviour is not part of this matrix, Oinas-Kukkonen (2013) state that quitting a behaviour often entails forming behavioural pattern (F).

As a second element of the persuasion context, the **'event'** must be considered. A central part of the event analysis is to consider the use context and in particular the features arising from the problem domain. The characteristics of the user also need to be considered. For example, people have individual differences which influence their information processing, such as differences in the need for cognition. Furthermore, developments in the user's life may influence how they process persuasive messages. Additionally, the understanding of the user's goals is important, which includes current progress toward achieving them, and past experiences with regard to the goals. Finally, self-efficacy needs to be taken into account. Building on the original PSD model, Halttu et al. (2015) have extended the event model to cover the situational **use context**, the long-lasting **user context**, and the **technology context**. The situational context is comprised of personal (e.g. evoked emotions), physical (e.g. location), privacy (e.g. the private or public nature of use), and task-related factors. The user context is comprised of personality and social factors, while the technology context includes service factors and device factors.

The **strategy** comprises the analysis of the message that is delivered through the BCSS to induce behavioural change, as well as the choice between a direct and indirect persuasion approach. The route selection depends on the information processing capabilities and motivation of the user to evaluate the

[1] In the table, C- means Complying, B- means Behaviour, C- means Change

content of the persuasive message. In cases the user is able to do so, a direct route is opportune. Otherwise, an indirect route needs to be taken. Note that given the abundance of information users in the information era are confronted with, users increasingly rely on indirect routes to process information.

Persuasive software features

Finally, the persuasive software features must be considered. Oinas-Kukkonen (2013) and Oinas-Kukkonen & Harjumaa (2009) distinguish primary task support, compute-human dialog support, system credibility, and social influence as persuasive system principles. The principles should be perceived as optional elements rather than requirements for each BCSS. The design principles for each of the categories are summarized in Table 2.

Table 2: Design principles for behavioural change support systems (Oinas-Kukkonen & Harjumaa, 2009)

Principle	**Description**
Primary task support	
Reduction	A system that reduces complex behaviour into simple tasks helps users perform the target behaviour, and it may increase the benefit/cost ratio of a behaviour.
Tunnelling	Using the system to guide users through a process or experience provides opportunities to persuade along the way
Tailoring	Information provided by the system will be more persuasive if it is tailored to the potential needs, interests, personality, usage context, or other factors relevant to a user group.
Personalization	A system that offers services has a greater capability for persuasion.
Self-monitoring	A system that keeps track of one's own performance or status supports the user in achieving goals.
Simulation	Systems that provide simulations can persuade by enabling users to observe the immediately the link between cause and effect.
Rehearsal	A system providing means with which to rehearse a behaviour can enable people to change their attitudes or behaviour in the real world.
Dialogue support	
Praise	By offering praise, a system can make users more open to persuasion.
Rewards	Systems that reward target behaviours may have great persuasive powers.
Reminders	If a system reminds users of their target behaviour, the users will more likely achieve their goals.
Suggestion	Systems offering fitting suggestions will have greater persuasive powers.
Similarity	People are more readily persuaded through systems that remind them of themselves in some meaningful way.
Liking	A system that is visually attractive for its users is likely to be more persuasive.
Social role	If a system adopts a social role, users will more likely use it for persuasive purposes.
System credibility support	
Trustworthiness	A system that is viewed as trustworthy will have increased powers of persuasion.
Expertise	A system that is viewed as incorporating expertise will have increased powers of persuasion.
Surface credibility	People make initial assessments of the system credibility based on a firsthand inspection.
Real-world feel	A system that highlights people or organization behind its content or services will have more credibility.
Authority	A system that leverages roles of authority will have enhanced powers of persuasion.
Third-part endorsements	Third-party endorsements, especially from well-known and respected sources, boost perceptions on system credibility.
Verifiability	Credibility perceptions will be enhanced if a system makes it easy to verify the accuracy of site content via outside sources.
Social support	
Social learning	A person will be more motivated to perform a target behaviour if (s)he can use a system to observe others performing the behaviour.

Social comparison	System users will have a greater motivation to perform the target behaviour if they can compare their performance with the performance of others.
Normative influence	A system can leverage normative influence or peer pressure to increase the likelihood that a person will adopt a target behaviour.
Social facilitation	System users are more likely to perform target behaviour if they discern via the system that others are performing the behaviour along with them.
Cooperation	A system can motivate users to adopt a target attitude or behaviour by leveraging human beings' natural drive to co-operate.
Competition	A system can motivate users to adopt a target attitude or behaviour by leveraging human beings' natural drive to compete.
Recognition	By offering public recognition for an individual or group, a system can increase the likelihood that a person/group will adopt a target behaviour.

The complete persuasive system design process model, containing persuasion postulates, the persuasion context, and finally the persuasive software features are depicted in Figure 2.

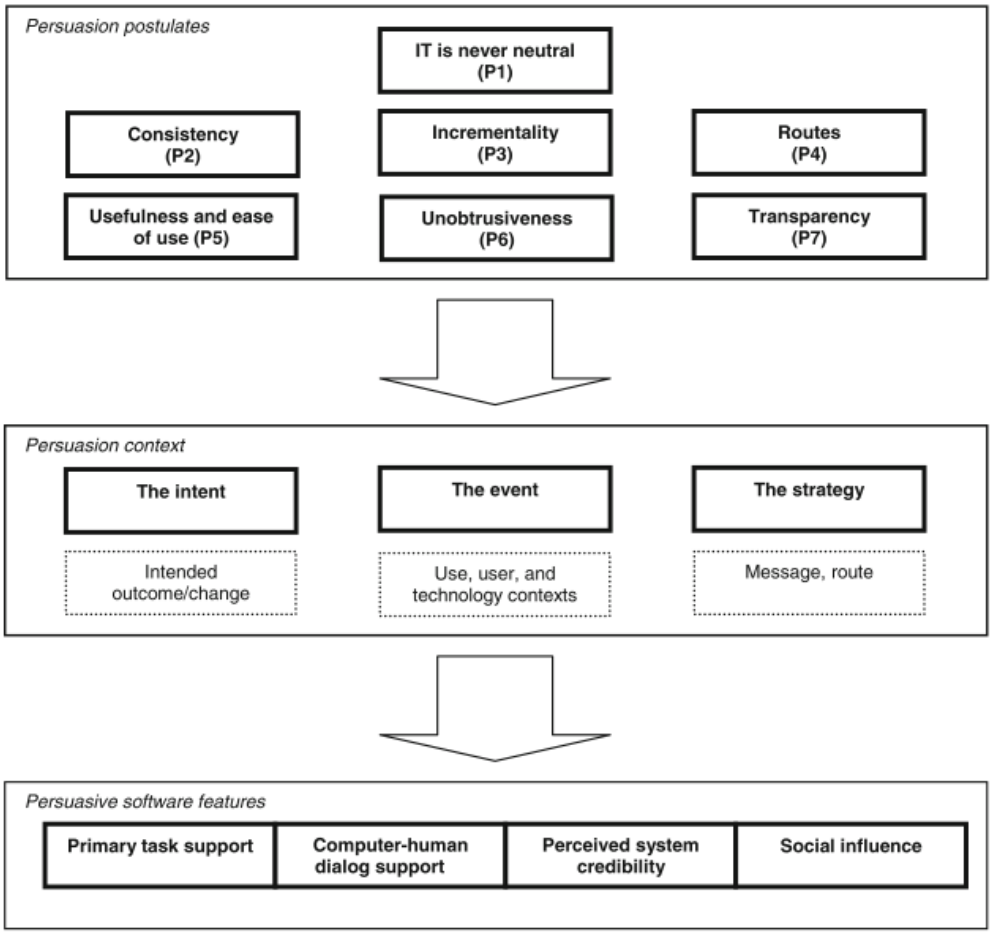

Figure 2: Persuasive System Design model (Oinas-Kukkonen, 2013)

As the design postulates are argued to be applicable to all persuasive systems, they would need to be carefully tested against empirical evidence to be treated as such. Even though the authors evaluate exemplary studies in the light of the PSD model, no specific evidence is provided for the validity of the design principles. Also, the principles can to be elaborated and tailored to the specific setting of behavioural change support systems to be practically useful. In a recent review of the state-of-the-art in

persuasive systems theory, Spagnolli et al. (2016) raised a number of issues designers should take into account:

- Users of persuasive systems should be empowered to perform a behaviour and be able to reflect on it, in order to avoid the so-called punishment-reward trap, which refers to a simplistic persuasive rationale where users are merely being conditioned to behave in a certain way.
- The individual factors (or behavioural determinants) that predict the targeted behaviour should be identified and analyzed in detail
- Contextual aspects must be taken into account, particularly in cases where there is an interdependency between other people. In such cases, when an indiviudal changes his/her behaviour, also the routines of other people are affected. For these situations, the focal point should move away from the individual to the network of individuals and resources (Spagnolli et al., 2016).

3.3 ATTENTION TRIGGERS

From the Fogg model (Fogg, 2009) and the PSD model (Oinas-Kukkonen et al., 2013) two contrasting requirements for persuasive systems can be derived. On the one hand, Oinas-Kukkonen (2013) argue that interference with the primary task the user is doing should be avoided, while on the other hand Fogg (2009) argues that a trigger is needed for behavioural change to happen. This implies that the design of unobtrusive yet strong enough attention triggers is an important part of persuasive system design. In enCOMPASS, this is particularly important, considering the low-involvement of users with their energy consumption, as well as the mostly habitual, unconscious nature of most energy consumption behaviour. In such cases, triggering the attention of the users is a precondition for success.

The design of attention triggering mechanisms is a non-trivial task, as in recent years, users' attention has become an increasingly scarce resource and valuable currency (Pielot et al., 2015a; Davenport & Beck, 2002). Companies such as Facebook and Google have centred their main business models around this currency, by providing free services to users in exchange for their attention (Pielot et al., 2015a), playing a major role in coining the term attention economy (Davenport & Beck, 2002).

On computers, and especially on smart phones, more and more apps and services, advertisements and system updates are trying to get the attention of users and customers through various notifications. However, both human information processing capacity and human attention are limited. As a result of the increase in information users need to process, they experience increasingly more difficulty to cope with the mass of information they are exposed to. E.g., in their one-week, in-situ study of mobile phone notifications, Pielot et al. (2014) involved 15 mobile phone users and found that participants received 63.5 notifications on average per day, mostly from messengers and email. This can lead to a state referred to as information overload: a state where the input to a system exceeds the processing capacity (Gomez-Rodriguez et al., 2015).

To users, a notification has a value, because it conveys some important information about an event, and a cost, because it interrupts them in their current task and possibly disturbs their environment (Kern & Schiele, 2003). Especially when interrupted in unsuitable situations, users are more likely to get annoyed by notifications and similar attention triggers than to pay attention and take the time to follow-up (Pielot et al., 2014). Unwanted notifications can also lead to stress and increased frustration, because users feel pressured to address the alerts (Pielot et al., 2014; Mark et al., 2008 as cited in Poppinga et al., 2014), and even decreased performance in the workplace (Czerwinski et al., 2004). At this point, mainly notifications from people whom users are close to are likely to be noticed and responded to (Pielot et al., 2015a). There,

an increasing number of received messages and social network updates can also evoke positive feelings and strengthen the sense of connectedness (Pielot et al., 2014).

This information overload means that one needs to understand when and how to present a notification in such a way that ideally, users notice it, are not annoyed by it, and respond to it, either directly or at a later, more suitable point in time. From the users' perspective, notifications and attention triggers are often referred to as *(human) interruptions* (e.g. McFarlane & Latorella, 2002; Czerwinski et al., 2004), and suitable points in time when to present such triggers as *opportune moments* or non-disruptive moments (Pielot et al., 2015a; 2015b; Poppinga et al., 2014; Pejovic & Musolesi, 2014). Another term that is also used in this context is the *interruptibility* of a user, assuming that interruptions between *coarse breakpoints*, i.e. major changes in the workflow, annoy users less (Poppinga et al., 2014). E.g., Fischer et al. (2011) found that a user responds to a notification more quickly if triggered at coarse breakpoints, e.g. after making voice calls or receiving SMS, assuming that the endings collocate with naturally occurring breakpoint in the user's primary task. In this case however, one needs to distinguish between three cases. In the best case, the user did in fact finish a task, both physically and cognitively, and is susceptible to interruption. Alternatively, the user may have just finished sub-tasks within a larger activity, or in the worst case, is already planning the next task (Fischer et al., 2011).

Previous research has identified four primary design solutions for coordinating interruption, i.e. immediate, negotiated, mediated, and scheduled interruptions (McFarlane & Latorella, 2002; McFarlane, 2002). An *immediate* solution for coordinating interruption would mean that the interruption occurs at any random time, requesting immediate attention of the human (McFarlane & Latorella, 2002). A *negotiated* solution would announce the need to interrupt first and then support a negotiation, e.g. for when the best time of interruption would be (ibid.), allowing the interrupted human different choices: (a) take-up with full compliance, (b) take-up with alteration (e.g., "remind me later"), (c) decline ("skip this version" in the case of a suggested update), or (d) withdraw (Clark, 1996, as cited in McFarlane & Latorella, 2002). *Mediated* interruptions use indirect information, e.g., a human's digital calendar or environmental sensors, to identify opportune moments for triggering notifications (Poppinga et al., 2014). A *scheduled* solution would restrict the interruption to a prearranged schedule, e.g. once every 15 min, or by explicit agreement for a one-time interruption (McFarlane & Latorella, 2002).

In their mediated interruptions approach, Fogarty et al. (2004; 2005) have identified opportune and non-disruptive moments for workers using stationary desktop computers and additional sensors in conjunction with self-reported feedback on interruptibility (experience sampling, triggered and recorded via audio prompts and microphone). The authors demonstrate that sensor-based statistical models of human interruptibility can provide robust estimates for a variety of office workers, with accuracy as good as or better than people self-reporting their current interruptibility (Fogarty et al., 2004). Their approach combined sensor input with user-system interaction log data to determine whether subjects were working on certain less interruptible applications (Fogarty et al., 2004). They also found an indication for a difference in interruptability between different types of workers, comparing managers, researchers and interns in their study, in that especially managers have fewer moments of interruptibility than researchers or interns.

Adding to the work of Fogarty et al. (2004; 2005), Poppinga et al. (2014) focused on mediated interruptions on mobile phones. After collecting 6,581 notifications from 79 users via a MoodDiary app which asked about users' mood several times a day, followed by a question on the obtrusiveness (see Figure 3), they developed a model that predicts suitable moments to issue notifications with 77.85 % accuracy (ibid.), using smartphone sensors and context data (e.g. time, location). The most promising predictors they found

for opportune moments were the time of day and the angle at which the user held the device. For the average user, before 8:21 a.m. and after 8:20pm, yet not too late at night, were the most suitable times to respond to notifications. When the phone was tilted by approximately 60%, i.e. the angle that typically indicates that the user is holding the phone in their hand, users responded to more than every second notification (Poppinga et al., 2014). Overall however, their predictive model only performed slightly better than random predictions, i.e. many notifications still occurred at inopportune moments. And even if the opportune moment was predicted correctly, they did not assess in their study whether users would actually act on the notifications.

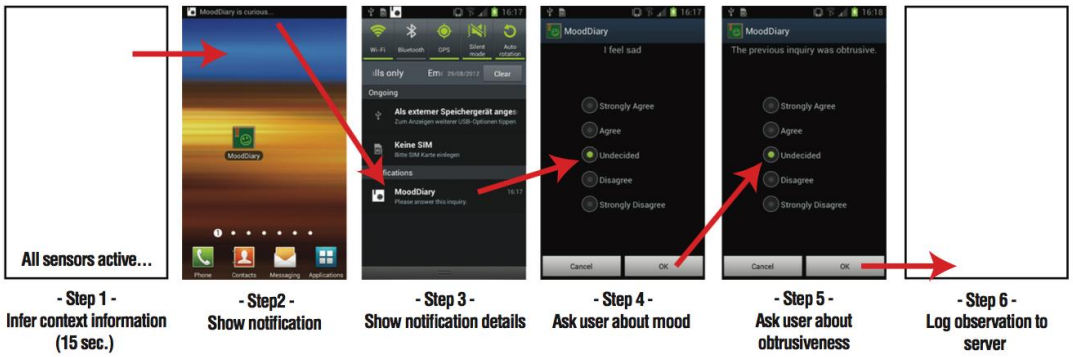

Figure 3: Process for issuing and answering a notification in MoodDiary app. In steps with user interaction (3-5), users can reject the notification. In Poppinga et al., 2014.

Rather than taking the scarcity of human attention as a starting point, Pielot et al. (2015a; 2015b) assume that "attention is abundant, rather than scarce, when a person is bored", as bored people tend to be actively looking for stimulation (Eastwood et al., 2012, as cited in Pielot et al., 2015a), and mobile phones are often turned to when people are bored (Brown et al., 2014, as cited in Pielot et al., 2015a). From that perspective, optimizing the moment at which a notification is delivered not only means that conflict with primary tasks should best be avoided, but also that the inference of times of boredom would improve the user's receptiveness to notifications. Pielot et al. (2015a; 2015b) inferred phases of boredom from patterns of mobile phone usage as opportune moments to present pro-active recommendations. In their study, experience sampling was used to collect subjective data on the users experiencing boredom. For this purpose users received a notification that requested a response to the statement: "Right now, I am feeling bored." (Pielot et al., 2015a). In a real-world study with 54 participants, their models to predict boredom have reached accuracies (area under ROC) ranging from 74.6 to 82.9% (Pielot et al., 2015b). Key predictors of boredom were recency of communication activity, intensity of phone usage (e.g. battery drain, number of apps launched), context (hour of the day and proximity sensor), and basic demographics (Pielot et al., 2015a; 2015b). In a second study, Pielot et al. (2015b) also found that "users are more likely to engage with suggested content on their phones when they are bored".

In contrast to many other studies, Kern & Schiele (2003) also considered the social environment of the user, mapping the design space of notifications based on social interruptibility vs. personal interruptibility (Figure 4). Whereas Kern & Schiele (2003) have focused on public spaces, the social environment in other settings is also important to consider, as a result of social conventions, and expectations from other users of the same space. For example, interacting with notifications at home during dinner, or in the classroom violate social conventions, whereas in contrast browsing through notifications while one is home alone is unproblematic.

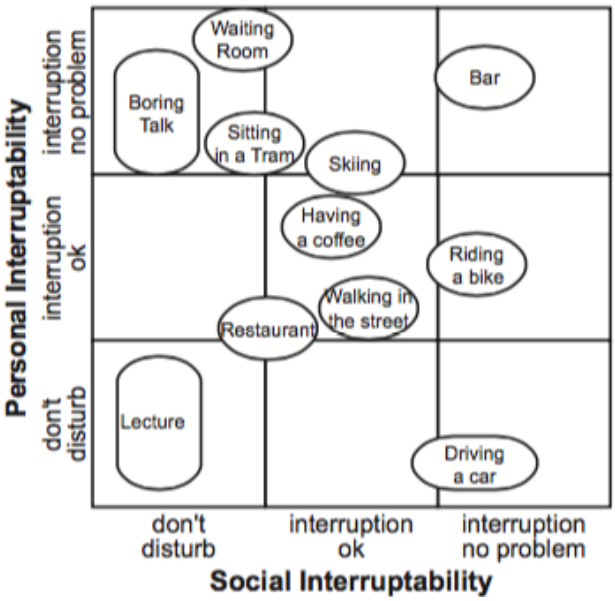

Figure 4: Design space of notification according to Kern & Schiele (2003).

Up to this point, work on the timing of notifications has been addressed without taking into account the persuasive context of the enCOMPASS applications. The persuasive context imposes a trade-off on designers of persuasive systems between unobtrusiveness on the one hand, and the effectiveness of behavioural change incentives on the other. Research on notifications in persuasive systems as a consequence strategy for behavioural change is however still in its infancy. As an exception, Tikka & Oinas-Kukkonen (2016) have experimentally compared user-defined timing of persuasive messages against random timing. The differences between the groups in terms of task success, task satisfaction, and unobtrusiveness ratings are not significant. However, Tikka & Oinas-Kukkonen (2016) found out that when using a system that sends messages, reminders and evaluation requests at random times, better perceived performance and higher satisfaction in one's own achievement do not seem to translate into an unobtrusive experience of the system. Regrettably, the authors do not report on the differences between the type of incentives they have scheduled to deliver at random or controlled by the user, which is probably caused by the small sample size.

In other words, still relatively little is known about how, and when to deliver behavioural change messages such as notifications. The use of adaptivity is a promising direction, implying that the delivery of such messages is adjusted to the context of use, leveraging the potential of context data available from the user.

In addition to understanding when to interrupt users with a notification, it is also key to know how this should be done, by considering e.g. the notification **style and intensity**. McCrickard et al. (2002) identified the following three design dimensions for notifications: *interruption* to primary tasks, *reaction* to specific notifications, and *comprehension* of information over time. As the dimensions can be considered as competing against each other, the authors propose to define successful notification systems design as achieving the desirable balance between attention and utility. In addition to the challenge of when to interrupt a user, McCrickard et al. (2002) point out that if new information should be detected by users with short, quick glances, it's important to understand the reaction to notifications, considering e.g. how information can be highlighted using colours, shapes, and motion. Comprehension is also an important aspect because even if users are unwilling to accept a primary task interruption at a given moment, they may desire high levels of comprehension over time (ibid.). In experiments, McCrickard et al. (2002) explored the design space of notifications on a secondary animated screen, which interrupted a primary

task on the first screen. More specifically, they investigated different types of notification animation – ticker, fade, blast – and analysed trade-offs between the three dimensions.

In the context of a surveillance system for police officers, Streefkerk et al. (2007) for example distinguished notifications based on salience and information density, arriving at two rules: 1. If message priority is high, then use highly salient notification (e.g. flashing). 2. If user workload is high, then present more condensed information (e.g. more text). They found that such an 'adaptive notification' led to better performance and less intrusive messages than non-adaptive notification, especially in high workload situations, and subjective judgments showed a positive user experience with the adaptive notification system.

In conclusion, much work has been undertaken to predict opportune moments of users that would indicate a high level of interruptibility. Naturally, not all presented models can predict such moments equally well, but also apply different levels of complexity in their models. In the context of enCOMPASS, careful evaluation is needed to identify opportune moments to interrupt users with pro-active recommendations and other system notifications, e.g. whether mediated or scheduled interruptions would be more suitable. In addition to assessing interruptibility, the notification content and means of presentation also needs to be considered.

Furthermore, little is known about how to maximize the effect of persuasive messages in general and notifications in particular. The design of these notifications constitutes a research challenge that will be addressed in the design of the enCOMPASS system.

3.4 EMPIRICAL EVIDENCE FOR EFFECTIVENESS OF BEHAVIOURAL CHANGE SYSTEMS

The theoretical underpinnings and the argued potential of behavioural change support systems to induce a change in behaviour or attitudes, the reviewed models do not provide evidence for the effectiveness of using ICT-based behavioural change solutions to change the behaviour. Hamari et al. (2014) have performed a systematic review on empirical studies that do provide evidence for the effectiveness of the designed behavioural change systems.

For their review they have proposed an abstract framework that connects motivational affordances, to psychological outcomes, and behavioural outcomes. Motivational affordance refers to "the properties of an object that determine whether and how it can support one's motivational needs" (Zhang, 2008, p. 145). Their model is depicted in Figure 5.

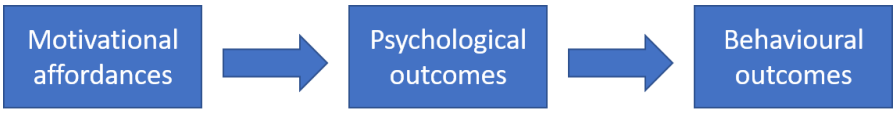

Figure 5: Conceptual framework in Hamari et al. (2014).

The assumption behind the model is that motivational properties of a behavioural change system determine to which extent people use it, which make it more likely that first psychological outcomes, and subsequently behavioural outcomes are achieved.

On the basis of this framework, Hamari et al. (2014) have reviewed 95 studies in 89 papers that each reported evaluation results of a particular behavioural change support system. The 95 studies originated from different domains, as can be seen from Table 3.

Table 3: Application domain in studies reviewed in Hamari et al. (2014, p. 126)

Application domain	**No. of studies**
Health, exercise	45
Ecological consumption and/or behaviour	20
Education, learning	10
Economic, commercial, marketing	6
Security, safety	6
Entertainment	2
No specific domain	6

As can be seen from the table, twenty studies were concerned with 'ecological consumption and/or behaviour'. Of these 20 studies, Hamari et al. (2014) found positive behavioural outcomes in 11 studies. Eight studies yielded partially positive behavioural outcomes, while only one study yielded negative outcomes. These results endorse the persuasive potential of behavioural change support systems in inducing pro-environmental behaviour.

A large variety was found between the studies that were reviewed, in terms of the motivational affordances that were applied. The affordances and associated number of studies that employed them are listed in Table 4.

Table 4: Motivational affordances found in the review by Hamari et al. (2014, p. 124)

Motivational affordance	**Total no.**
Visual or audio feedback	25
Social support, comparisons, feedback, interaction, sharing	22
Progress	16
Persuasive messages and reminders	16
Objectives and goals	15
Rewards, credits, points, achievements	16
Ambient or public displays	13
Social agents	12
Competition, leaderboards, ranking	12
Emoticons and expressions	8
Suggestions and advice	6
Tracking	3
Video-based persuasion	3
Positive reinforcement	2
Subliminal persuasion	1
Not specified	9

A similar wide range of psychological outcomes were evaluated, covering predominantly motivation-related outcomes (e.g. engagement, encouragement, motivation, enjoyment, fun), and to a lesser extent psychological antecedents of the target behaviour (e.g. awareness, attitudes, self-efficacy). Few negative attributes were assessed (e.g. frustration, cognitive overload, guilt, anxiety).

Interestingly, in the evaluation of these persuasive systems, little attention has been paid to social influences. Only in one study peer pressure was measured, and in one study sense of community. This is

surprising since social dynamics between group members are important predictors of behavioural outcomes, and as such need to be assessed to understand the presence or absence of behavioural effects (e.g. Hargreaves et al., 2013; Spagnolli et al., 2016).

In the 95 studies a wide variety of motivational affordances were evaluated. The affordances implemented most often were visual and audio feedback (25), social features (22), progress and persuasive messages (16), reminders (16), and objectives and goals (15). The popularity of the social features is testimony of its proven effectiveness for inducing (pro-environmental) behavioural change (e.g. Abrahamse & Steg, 2013).

3.5 CONCLUSION

In this section the theoretical and empirical foundation of behavioural change systems has been addressed. For enCOMPASS, the models and associated design principles provide insights into the range of system features that can be employed to induce a change in energy consumption behaviour. Additionally, the importance of attention triggering has been highlighted, with a focus on adjusting notifications to the context of the user, to avoid disrupting his/her primary task performance. While a lot of open questions are not yet answered by the presently available research, the lessons learnt from this section can function as input to the requirements analysis in WP2.

4 INCENTIVE STRATEGIES AND ALGORITHMS IN GAMIFIED APPLICATIONS AND GAMES WITH A PURPOSE

Motivation theories and persuasive system design principles are keys for the development of a class of digital applications directed to the general public, which must engage their users for the purpose of fulfilling a given task or inducing behavioural change. The operationalization of motivation theories and persuasive system design principles into the development of specific systems capable of engaging users is an active research subject of the **Human Computation** field, broadly defined as the area that studies the development of socio-technical systems where **humans and computers cooperate to address a task or achieve a goal**. This novel and broad class of socio-technical systems comprises **gamified applications** and **games with a purpose (GWAPs)**, the categories to which the enCOMPASS user awareness application belong.

4.1 HUMAN COMPUTATION, GAMIFICATION AND GAMES WITH A PURPOSE

The new computation paradigm of **Human Computation** (Von Ahn, 2009) is defined as an approach to digital system development in which the user interaction of users and among users is harnessed to help in the solution of tasks or attainment of a goal. According to (Quinn, 2011) a system belongs to the area of Human Computation when human collaboration is facilitated by the computer system and not by the initiative of the participants. The common baseline of the approaches that exploit humans in computing is the intelligent partition of functionality between machines and human beings: networked machines are used for task splitting, coordination, communication, goal attainment verification and result collection; humans participate with their intuition, behaviour and decision-making power (Parameswaran, 2011)

Human Computation can benefit the **management of environmental resources**, such as gas, energy and water, which are by definition shared and distributed and demand new approaches to their management, based on an increased consciousness of mankind's collective responsibilities. Traditionally, the management of natural resources has been performed with a centralized approach, based on static policies (usually coded as laws and regulations), thus neglecting the intrinsically dynamic nature of both the systems and the management processes ruling their evolution. Human Computation can open up opportunities for a continuous involvement of stakeholders, in all phases: from the definition of the objectives and of the performance indicators, to the development of formal models to characterize the system behaviour, down to the selection of the best and most appropriate management and even personal consumption decisions.

Human Computation can assume a variety of forms, according to the scale at which humans are engaged, the tasks they are called to solve, and the incentive mechanisms that are designed to foster participation (Quinn, 2011). A number of principal approaches can be catalogued:

- **Gamified applications:** these are traditional application addressing a business goal (e.g., a water or energy online bill), extended with features normally found in games, to promote user's engagement and activity (Deterding, 2011).
- **Games with a Purpose (GWAPs):** focus on exploiting the billions of hours that people spend online playing with computer games to solve complex problems that involve human intelligence (Von Ahn, 2006 and Law, 2009). The emphasis is on embedding a problem-solving task into an enjoyable user experience, which can be conducted by individual users or by groups. Several game design paradigms have been studied (Law, 2009) and the mechanics of users' involvement has begun to be modelled

formally (Chan, 2009). GWAPs, and more generally useful applications where the user solves perceptive or cognitive problems without knowing, address such tasks as adding descriptive tags and recognising objects in images, checking the output of Optical Character Recognition (OCR) for correctness, helping protein folding and multiple sequence alignment algorithms in molecular biology and comparative genomic research (Cooper, 2010).

- **Social Mobilisation**: this approach addresses problems with time constraints, where the efficiency of task spreading and of solution finding is essential. The DARPA Network Challenge (Pickard, 2011) is an example of the problem and of the techniques employed to face it. The challenge required teams to determine the coordinates of ten red weather balloons placed at unknown locations in the United States. The winning team employed a novel recursive incentive mechanism that permitted them to locate all balloons in under nine hours. Applications are also found in safety critical sectors, like civil protection (Hamilton, 2011) and disease control (Stothard, 2011).
- **Human sensors**: this area of work leverages the pervasive diffusion of mobile terminals among the users, and, especially, the fact that more and more of these devices are equipped with sensors (Abdelzaher, 2007 and Campbell, 2008).The focus is on the real-time collection of data, in order to realize time-critical decision support systems and emergency management. Early application areas include pollution monitoring (Dutta, 2009), traffic and road condition control (Manasseh, 2009 and Bansal, 2011), and earthquake monitoring (Sakaki, 2010). Interestingly, human behavioural patterns in the usage of mobile phones have been exploited to detect level of activity, so to examine the effects of the spreading of seasonal diseases (Madan, 2010).
- **Crowdsourcing**: this approach focuses on the distributed assignment of work to an open community of executors (Howe, 2006). A typical crowdsourcing application has a Web interface that can be used by two kinds of people: work providers can enter in the system the specification of a piece of work they need (e.g., collecting addresses of businesses, classifying products by category, geo-referencing location names, etc.); work performers can enroll, declare their skills, and take up and perform a piece of work. The application manages the work life cycle: performer assignment, time and price negotiation, result submission and verification, and payment. In some cases, the application is also able to split complex tasks into micro-tasks that can be assigned independently (Huang, 2010), e.g., breaking a complex form into sub-forms that can be filled by different workers. In addition to the web interface, some platforms offer Application Programming Interfaces (APIs), whereby third parties can integrate the distributed work management functionality into their custom applications. Examples of crowdsourcing solutions are Amazon Mechanical Turk and Microtask.com. Application areas are the most varied: speech transcription, translation, form filling, content tagging, and user evaluation studies are a few examples.

In the following, we focus on **gamified applications and games with a purpose**, which are the categories of Human Computation that apply more deeply persuasive system design principles and are more related to the enCOMPASS approach.

4.1.1 Gamified applications

A **gamified application** is a traditional application addressing a business or environmental goal, extended with game-like features (Deterding, 2011), such as: the registration of users and the maintenance of their profiles and interaction history, the qualification of some actions as game actions, the establishment of achievements consisting of the successful completion of a set of game actions, the recognition of game actions and/or user's achievement with a system of rewards, and the insertion of users in a competition system. An example of gamified application can be a technical support web site, where users sign up to perform a number of business actions, like signaling bugs or requesting help. Some of the user's actions can

be considered as game actions and associated with a reward, for example with a number of points. Achievements can also be defined, for giving special rewards to the most active users: for example, users recognized as helping other users may achieve the status of "experts". Finally, the status of users can be made public, for example in a leader board, so to promote the most performing users and stimulate participation. The aforementioned gamification features can be added to an application for a variety of objectives: to improve user engagement, ROI, data quality, timeliness, and to learn a particular task or business activity (Herger, 2012). Table 5 lists some exemplary gamified applications, specifying their business goal and their principal gamification features.

Table 5: Examples of Gamified Applications in different sectors

Application	**Goal**	**Gamification features**	**Reference**
Zamzee	To promote physical activities among children	Levels, Real world challenges, Leaderboards, Achievements, Physical and Virtual goods	https://www.zamzee.com
Innov8	To promote the use of BPM and SOA to solve traffic and supply chain problems	Competition, Leaderboard, Physical Goods, Feedback	http://www-01.ibm.com/software/solutions/soa/innov8/index.html
OPower	To encourage people to save energy	Goals, User Comparison, feedback	https://www.oracle.com/corporate/acquisitions/opower/index.html
RecycleBank	To help reduce waste and adopt green behaviours	Points, Physical Goods, Referral, Real world challenge	https://www.recyclebank.com/
LiveOps	To motivate call centers operators	Points, Leaderboards	http://www.liveops.com/
Mulino Bianco, Barilla	To increase the participation in marketing campaigns and the acquisition of suggestions and new content from users	Achievements, Personalized profile	http://www.mulinobianco.it/i-talenti-del-mulino
WebRatio Community	To encourage users to submit software components to a repository and test/rate existing one, and actively participate on the forums.	Points, Leaderboard, Physical and Virtual goods	http://www.webratio.com/community/getting-started
Samsung Website (Samsung Nation)	To encourage user to post product reviews, and participate in user Q&A discussions,	Points, Badges, Progress Levels	http://www.samsung.com/us/welcome_BV.html
Fitbit	To help users to improve in the fitness activities and goals	Point, badges, Goals, Real world challenges, user competition	https://www.fitbit.com/app
Khan academy	To improve user skills in topics related with math, physics, chemistry, etc.	Points, level, missions, skill-growth trees	https://www.khanacademy.org

4.1.2 Games with a Purpose (GWAPs)

A **Game with a Purpose** is a game, in which players generate useful data or assume novel behavioural patterns as a by-product of play (Von Ahn, 2006). GWAPs normally employ pre-existing game genres (e.g. action, puzzle, word, simulation games) and embed a task in the most appropriate game action. Table 6 lists some examples of GWAPs, specifying the game genre and the associated task.

A first distinction between gamified applications and GWAPs lies in the motivation for their development: application gamification normally serves the purpose of increasing the performance of users of an existing application with respect to given business or sustainability objectives. Conversely, GWAPs address a particular computational task or behaviour change goal with an ad hoc application exploiting human intervention. This difference induces a kind of symmetry between the two types of effort: in application gamification, predefined business actions are mapped to game actions; in GWAP design, game actions predefined in the game genre are mapped to useful tasks.

A second distinction, derived from the first one, is the phase in the development cycle in which the game mechanics are introduced. In the case of gamified applications, the introduction of gaming elements is normally subsequent to the business application design phase; an application, developed as a traditional enterprise or web application, is extended a posteriori by applying gamification techniques. This antecedence partially holds also in the case in which gamification is planned a priori for a novel application: the desired functionality drives the application requirements specification and gamification features are added as a crosscutting concern, in order to improve the effectiveness of the application with respect to the original goals. In the case of GWAPs, a reverse antecedence holds: the gaming experience is created along with the definition of the problem that must be solved, but the style of interaction is preexisting and codified in the chosen game genre.

To summarize, three commonalities characterize GWAPs and gamified applications:

- One or more objectives or tasks that users should accomplish.
- A gaming experience, defining challenges to overcome and rewards for their solution.
- One or more players, the users of the application, who are profiled and monitored in their activity.

Table 6: Examples of GWAPS in different sectors

Game	Genre	Task	Mechanics	Reference
ESP	Puzzle Logic	Image Tagging	Collaboration	(Von Ahn, 2004)
Verbosity	Puzzle Logic	Commons Sense	Question/answer/ guessing	(Von Ahn, 2006)
LQG	Puzzle Logic	Translation Assessment	Question/answer	(Britton, 2013)
FoldIt	3D Puzzle	Configuration Matching	Protein Folding	(Madani, 2017)
Peekaboom	Puzzle Hidden Object	Objects recognition and segmentation	Show & Guess	(Von Ahn, 2006, April)
Sketchiness	Puzzle Draw& Guess	Objects recognition and segmentation	Draw & Guess	(Galli, 2012)

4.2 GAMIFICATION AND GWAP DESIGN PRINCIPLES AND MODELS

enCOMPASS requires a flexible incentive model supporting different motivations for needs and expectations of a diversified set of users. In enCOMPASS 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 gamified application and game design process. Applications of user-centred design principles are necessary to avoid meaningless, or even harmful, gamification. Scott Nicholson et al. (Nicholson, 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 that analyze the player types, gameplay environment, emotional responses to gameplay, and the relationship between motivation and ability in games. The models help to understand how game and gamified application designers can make people want to play or engage and persist in their activity, given the differences in motivation among participants.

4.2.1 Bartle's Player Categorization

Different players have various desires in games and their important factors of the game are also different [Fraternali, 2016]. 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 (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.

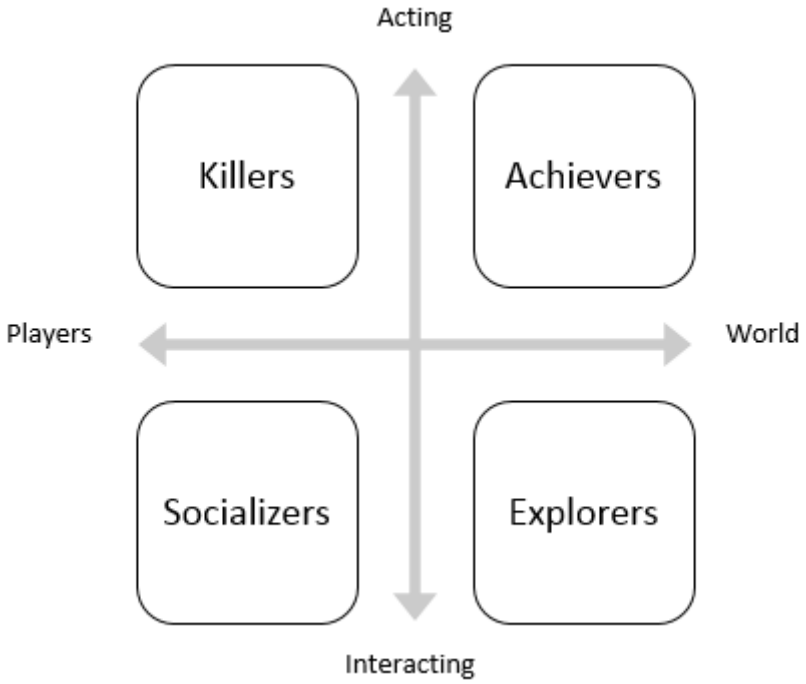

Figure 6: Bartle's player categorization

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.

4.2.2 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 7).

According to Kim (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 collaboration over competition. 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, it is also 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 8 shows more actions relating to her point of view.

Figure 7: Ami Jo Kim's view on Bartle's model.

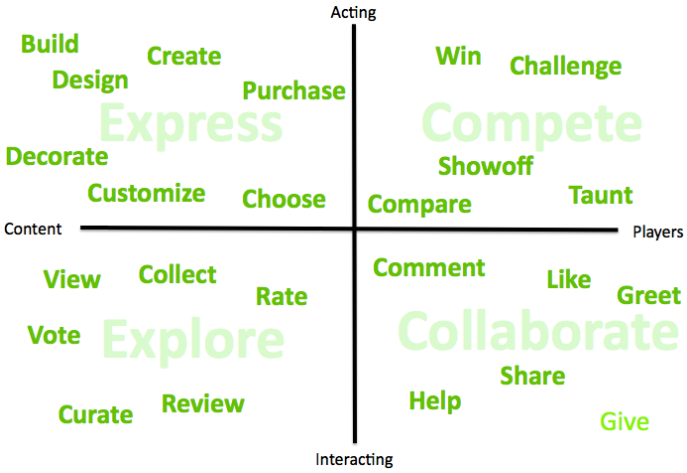

Figure 8: Ami Jo Kim's Social Engagement Verbs.

4.2.3 Radoff's Gameplay Model

Jon Radoff uses two axes to define the environment the player: horizontal axis and vertical axis as shown in Figure 9 (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.

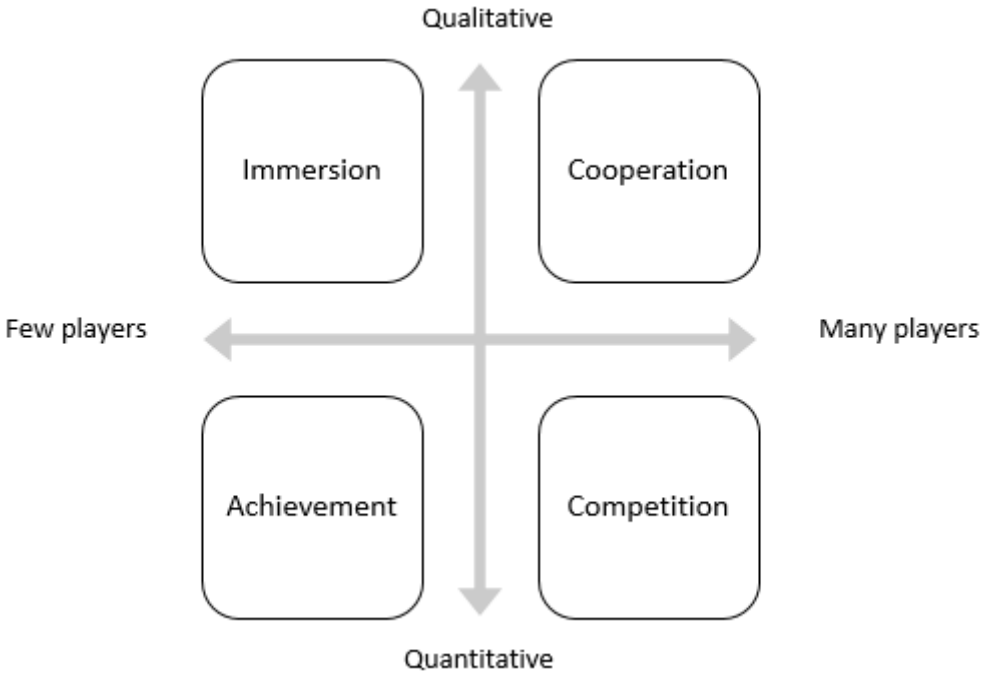

Figure 9: Radoff's gameplay model.

4.2.4 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.

4.2.5 The Hexad framework

Andrzej Marczewski [Marczewski 2015] proposed a gamification user typology model that aims at relate the user personality to the gamification elements in order to provide a customized experience in terms of motivators and improve engagement. The model is based on a research on human motivation, player types, and hands-on design experience [Tondello 2016].

The proposed typology enables the classification of users of gamified systems based on intrinsic (perception of an activity been enjoyable, entertaining or fulfilling) and extrinsic (expected outcomes of executing a task, i.e. getting rewards) motivational factors. It consists in 6 main user types:

- **Socialisers**: motivated by interaction and social connections.
- **Free Spirits**: Their motivation is driven by creation, autonomy and exploration.
- **Achievers**: They are in a constant search for challenges, self-improvement and skill mastery is their main motivation.
- **Philanthropists**: The search for purpose and meaning in the activities, helping others is their motivation and reward.
- **Players**: Seek to collected rewards and to compete.
- **Disruptors**: They are motivated by change, they aim at disrupting the system in positive or negative ways.

Figure 10 Marczewski's User Types Hexad framework [Tondello 2016]

These types are then divided in 3 categories: Intrinsic, extrinsic, and disruptors. **Intrinsic** user types motivation is strongly related with the activities or tasks they perform, motivation raises from the enjoyment and the engagement of the user in the task itself, user groups in this category are: Socialisers, free spirits, achievers and philanthropist. **Extrinsic** user type is mainly formed by "players", this group is mainly drive by rewards and can be subdivided in 4 subtypes that are analogous to the intrinsic types: Self-seeker are like philanthropists but they expect a reward for their help or contribution; Consumers are like achievers they will learn or develop skills if there is a reward involved; Networkers are like socializers but they search connections they can benefit from; and finally exploiters that are like free spirits, but the explore the boundaries of the systems searching for ways to gain rewards from errors or holes in the system. The last category involves the "**Disruptors**", who seek to disrupt other users or the system itself in

any feasible way. They are divided in 4 subtypes: Grievers, their only motivation is to affect other users in a negative way; Destroyers, that will try to break the system by hacking it or finding bugs; Influencers, this type tries to change the way the system works by using their influence on others; and improvers, that are an ethical hacking type of user, they try to find problems in the system and fix them or report them.

The model proposes to identify the user types in the systems and design the gamification elements according to the motivation of each type, e.g. provide "Socialisers" with social networks connectivity, statuses and elements of social pressure; design challenges, quest and badges for "Achievers"; create customization and exploration features for "Free Spirits"; and provide creativity tools and voting mechanisms for "Disruptors" in order to changes their mindset toward a positive interaction or use their influence to change and improve the system.

4.3 OVERVIEW OF GAMIFIED SYSTEMS FOR SUSTAINABILITY AND SUSTAINABLE CONSUMPTION

We now overview a number of relevant projects and applications aimed at the design and implementation of gamified applications and GWAPs in the context of sustainability and consumption awareness enhancement. We note several similarities among case studies that address water and energy management, due to the fact that these two sectors are assimilated by mostly the same motivations and design principles for inducing a behavioural change towards more efficient resource usage.

4.3.1 Ecogator

Ecogator[2] is an efficiency advisor smartphone application designed within an IEE (Intelligent Energy Europe) funded project, in a collaboration of 12 partners from 10 European countries, it is focused on efficient energy consumption.

It provides two operation modes: the shopping mode assist consumers at sale points to identify the most efficient appliances, the day-to-day mode aims to increase awareness of sustainable and efficient use of products [Bogner 2015].

The features of the shopping mode include the possibility of scanning the appliances energy labels, using that information it provides the consumer with general information about the efficiency of the appliance like the annual running cost of the appliance and the total cost of the product life time, it also allows comparison between 2 scanned products to empower the user in the decision-making process (Figure 11). The day-to-day mode provides money saving and efficient energy use tips from 6 different categories.

The gamification concept consists in awarding points to the users for actions like scanning appliances labels, using the comparison or calculation functions, reading tips and execute social media actions as sharing tips. The points allow moving forward on a series of levels, a set of question and quizzes test the gained knowledge and present challenges to the user, when a certain level is reached the user is rewarded by entering a prize contest (Figure 11).

The application evaluation in real life indicated that EcoGator was perceived as a good shopping assistant but less powerful as a tool for raising awareness. The authors evaluated the application only in terms of user acceptance [Peham 2014].

[2] Ecogator http://www.myeconavigator.eu/

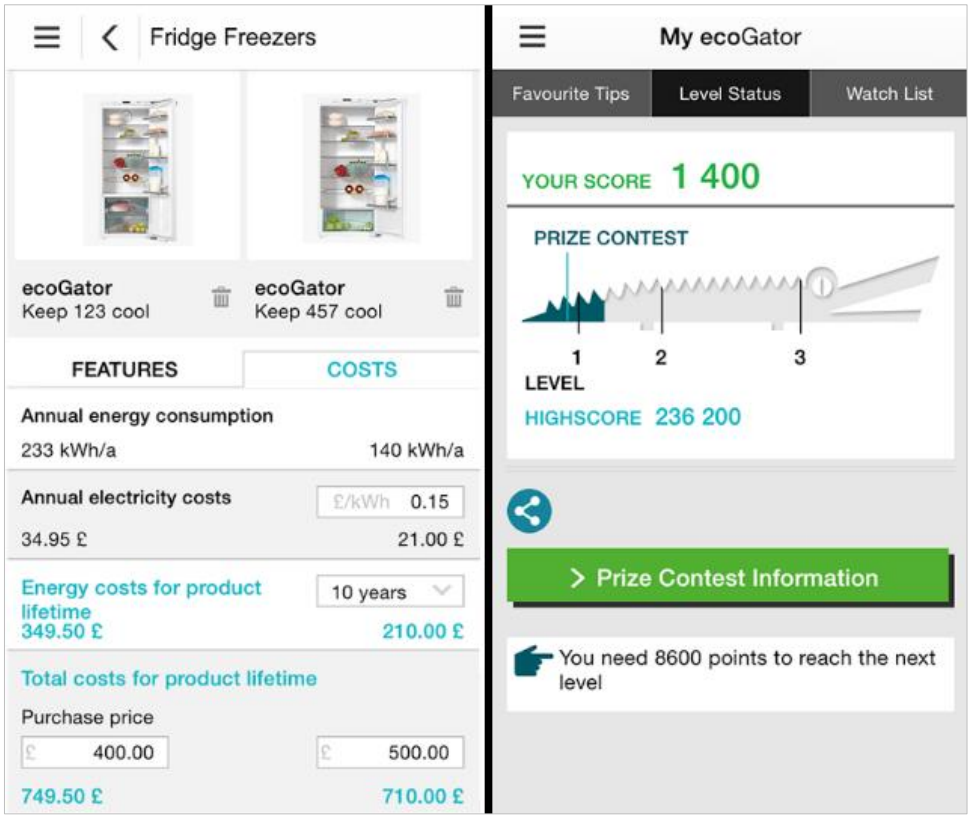

Figure 11: on the left the ecoGator appliance comparison function, on the right the ecoGator view displaying the score points and level [Bogner 2015].

4.3.2 Social Power Game

Social power game[3] is a project of the University of Applied Sciences of Southern Switzerland (SUPSI – Scuola universitaria professionale della Svizzera italiana) and the Zurich University of Applied Sciences (ZHAW – Zürcher Hochschule für Angewandte Wissenschaften). The project objective is to explore the potential of social interaction and game mechanics in driving people towards long term behaviour change in the field of sustainable energy consumption.

Social Power Game is a mobile game application that aims at encouraging energy saving through social interaction over an individual energy analytic approach. The application aims to connect an entire neighborhood to facilitate the collaboration and exchange between a multitude of people, to increase collective capacity-building for change (energy-saving practices); to support mutual improvement in the adoption of more sustainable life styles; and to favor the viral diffusion of best practices. This approach seeks to provide a collaborative, action-oriented model for social learning in the context of a challenging neighborhood-based energy-saving contest.

Among its features there is tracking of household electricity consumption in a personalized way with easy-to-read visuals; visualization of electricity consumption trend over time; visualization of the effect of user actions; team challenges to collaborate and compete; and information provisioning to user about how to make more efficient uses of energy.

[3] Social Power Project. http://www.socialpower.ch/

The gamification mechanism has 2 principal elements [DeLuca 2014]: the players that represent the household dimension, and the energy hives that represent collective and social dimension, they are energy-related points of interest like transport stop or infrastructure, grocery stores, etc.

When users register to the game they are assigned to one of the 2 factions or teams, and are provided with individual challenges like goals to reach, collaborative tasks like discovering the energy hives and report them in the application social map, and cooperation tasks that require coordination with others in order to complete the mission. The players get points by completing any of those tasks; they also receive information about how to make efficient use of the shared resources.

Another objective of the game is to raise awareness of the energy use in user's surroundings. The competition takes place between teams (or factions) through visual comparison of the actions of each team including achieved points, average consumptions, and the player's contribution to his team achievements. Players are awarded badges for their individual achievements and for continuous or outstanding contributions to their teams [DeLuca 2014].

What is interesting and different on this work is that here the social interaction is meant and perceived more in terms of collaboration, considering that there are social dynamics in addition to badges and rankings. Some preliminary results from the pilot show that 75% of the households participating in the project reduced their historical consumption between 1% and 25% [Castri 2016].

Figure 12: Social Power Dashboard

4.3.3 Makahiki

Makahiki[4] is a project of the University of Hawaii, and developed by George Lee. It was first introduced during the energy dorms competition of the university, as part of the Kukui Cup challenge[5], on 2011. Makahiki is an open source game engine to motivate people's awareness of energy conservation.

[4] Makahiki 2 Documentation. http://makahiki.readthedocs.io/
[5] Kukui Cup project. https://kukuicup.org/

It facilitates the implementation of "serious games" that motivate players to learn about energy issues, improve their intuition about energy consumption, and understand how to use energy more efficiently in their normal life [Lee 2012a].

The engine integrates with Watt Depot[6], that is an open source web service developed also by the University of Hawaii, which purpose is to collect power data from the sources and store it, the service provides near real-time intervals for consumption tracking.

The project also uses google visualizations to present electricity consumption data in a dynamic and understandable way, the visualization can be personalized by the user adding profile information and tracking their actions, events and commitments. As the software is intended for university dorms visualization allow comparison with other floors or other buildings.

To promote energy consumption awareness and as part of the gamification process the platform supports the creation of actions, commitments and daily energy goals. Actions go in example from replacing a light bulb in a desk lamp, to attending meetings organized by sustainability organizations. Commitments are requests made by the dorm administration, like committing to turning off the lights in the lounge when they are not in use. And finally, goals are actions that the entire dorm floors participate in [Lee 2012a].

Daily energy goals involve floor's members voting on how much they plan on reducing their floor's energy and then attempting to accomplish such goal, the players get points for any of these items.

The context where the application was deployed and tested was the following [Lee 2012a]: smart meters were installed in 4 student residence halls; towers (buildings belonging to a residence hall) and floors competed to minimize energy usage. In order to earn points, players should perform certain tasks and make public commitments to adopt more sustainable behaviours. Points were also aggregated to a get the floor's overall performance. The game included elements like the smart grid game (organizing tasks and commitments); the daily energy goal; the raffle game where people could earn a ticket to win a variety of prizes; two-people collaborative tasks and an additional layer for top players. To attract more players a referral system was set in which user received points for inviting their friends to the platform, and the new registered users got points by provide the email of the person that invited them.

As part of the evaluation of the platform four points highlighted: focus groups and usability evaluations improved the player experience; the game required a good, planned and intensive communication strategy for its adoption; identifying social influencer and incentivize them can create a positive impact in the adoption process; prizes and incentives had to be deeply analyzed and planned since it is hard to find right incentives when the player population is diverse. Their evaluation concerned only the user acceptance and feedback for the game [Lee 2012a].

This project proposed a different way to approach to gamification with respect with other projects reviewed, since it provides a gamification engine to facilitate the implementation tasks enabling developers to create more than one game, it also provided insight of the game mechanics design process where the user and the prizes have to be carefully considered, and it emphasizes the importance of exploiting social network information in order to enhance engagement on certain groups.

Similar projects and social experiments have follow a similar approach in other universities in the United States and Canada like "Do it in the dark" that encourage competition between student residences to

[6] WattDepot. http://wattdepot.org/

reduce their average consumption, the project included case of studies in Princeton(U.S.) and University of British Columbia (Canada) among others [Senbel 2014].

4.3.4 Power House

Power House is a project developed by the Stanford University; it is part of the Girls Learning Environment and Energy project (Glee[7]). It consists of an online game that connects home smart meters and social networks, while seeking to examine how the engagement mechanisms common in popular games may be leveraged to promote desired real-world energy behaviours [Reeves 2012].

The household information is track through his local energy provider and sent back to the game environment where it is used to influence player in-game behaviour and saving abilities, it also influences the player options, rewards and social reputation. The real-word consumption behaviour affects the development of the game producing advantages or disadvantages to the players.

Players are provided with a dashboard that displays information about the last 24 hours of consumptions; it also provides comparison with past data. Players can review their scores, the results of competitions with other players and teams and the number of virtual credits earned, virtual credits can be spent on in-game items, or on real world items provided by the utility company.

On the social features, there is a chat forum for the players to ask questions and make comments; at the virtual neighborhood view where players can visualize the houses and achievement of their friends; and the leaderboard that allows players to view their achievements and theirs team and compare them with the achievements of their friends, all these features are supported through Facebook connect; finally, the players can challenge their friends to energy competitions.

The gameplay consists on a virtual house where family members need to be assisted in their day-to-day activities by the player, the player oversees turning on and off appliances (lights, TV set, computer, coffee machine, etc.) and keep track of the activities of every member of the family as long as possible to reduce waste (Figure 13), the points system is based on the ability to minimize the amount of electricity consume by the family [Reeves 2012].

The game is designed to reflect in the virtual appliances the amount of energy consumption that they have in real life, in example the amount of kilowatts consume by the TV in a period of time, to enhance player awareness; to offers constant information about energy efficient use and to encourage players to challenge each other in saving competitions.

The project was tested in 2 settings [Reeves 2015], the first was a laboratory experiment where the subjects were asked to play the game for 30 minutes, during this time 5 appliances remained turn on, the result showed that the game positively affected the efficient use of energy perception as the subjects started to turn off the appliances after the gaming period.

The second setting was a field test in which subjects were asked to execute a series of task in the game that would take approximately 17 days, after this period it was observed that the energy consumption of the households where significantly lower than the 30 days after and 30 days later of the test. Both of these results show that the game was indeed able to positively influence the consumption behaviour of the players; however, the game mechanics were not able to influence the long-term behaviour.

[7] Girl Learning Environment and Energy. https://glee.stanford.edu/

In conclusion, the project proposed interesting ideas on how to keep the mindset of the users on making efficient use of the electricity, one of the key factors is to show the real consumption of the different appliances on screen and showing that by simple actions there is considerable savings, still as the real consumption is not strongly related with the game the effect vanishes fast, extra features to the mechanics would help to improve this point.

Figure 13: Power House gameplay: the game character is consuming energy by using the light in the kitchen; on the bottom, left corner the digital meter accounts for the overall consumption on the game .

4.3.5 LEY

LEY is a project of the University of Lisbon, it proposes a persuasive pervasive-based serious game approach to help people understand domestic energy usage and change their habits. The name "Less Energy Empowers You" (LEY) refers to the project vision to empower people to make a better use of resources by providing them with adequate tools [Madeira 2011].

The platform consists in three main components: A sensor platform, a supporting web-based information system and a mobile game application. The sensor platform provides with real time data to the mobile application and the web application, where the data is store along with the game rules, this system also provides data visualization to the historical data.

The game consists in two modes, the single mode where the players have the constant challenge to bring their energy consumption to the optimal level in order to achieve the maximum amounts of points, which are awarded to the player also by answering quizzes or inviting people to the platform. It is important to notice that the game ranks the consumption levels according to the official European energy efficiency rating, which presents the energy efficiency of residences on a scale of A (most efficient) to G, using this scale gives the user a real overall measurement of the efficiency.

The completion mode allows the players to challenge one or many other players into sustainability-based quiz competition that occurs during an established period, at the end of the period the users are ranked and presented with the results, the points are awarded according to the position on the ranking.

Other feature of the game is the house avatar of the mobile app through which the player can monitor the status of the consumption and receive alerts. The avatar can be personalized and the players can also set their profile information [Madeira 2011].

The project presents an interesting view for a decentralized monitoring option, which could encourage individual householder to set a monitoring system and gamify the resource consumption in competition among family members. The work is still in design face and no results are available yet.

4.3.6 Wattsup

Wattsup is a project of the Social Computer Center of the Lincoln University; the application is a Facebook-based application that displays energy consumption and CO2 emission data, giving the users the ability to compare household data with their friends. The aim of the project is to encourage energy saving by using live and historical energy feedback in a social-normative context.

The project consists on using Wattson Sensors and monitors [Wattson] to get and store the consumption information from the households, the data is then transmitted to a server where it is made available for the desktop application and the Facebook gamified app.

The project conducted a series of interviews with focus groups to determine what information was important for the users, derived from this study it was concluded that kilowatts where no representative enough for the users, and decided to add other measurements like the approximate amount of CO2 that is released to produce certain amount of energy and the approximate cost for the user's consumption [Foster 2010].

The Facebook application shows this information in 3 different views: My Energy, that shows user's current consumption; Friends, that compares the consumption against a selected friend; and Rankings, where the users are ranked on daily basis depending on their consumption, users are enabled to make comments on their ranks and view other people comments.

The experiment was conducted in 2 settings [Foster 2010]: on the first setting some users started using the platform without access to the Facebook application; on the second setting the users could access the application.

After an established period, the results showed that the first group lower the consumption thanks to the monitoring but the reductions of the second group was considerable higher (in total a difference of 130Kw units of energy saved between the two groups), while analyzing the data of the second group it was observed that the users spent most of the time on the rankings interface, viewing and commenting on the rankings table. The results suggest that social interaction can effectively motivate participants to reduce the household consumption [Foster 2010].

This project shows two principles of gamification that must be kept in mind, first the basic element of competition both direct and global through leaderboards, and second the power of social interaction as an engagement strategy and as a behaviour influencer (by social acceptance principle).

4.3.7 Urban Water Project

Urban Water[8] is a project funded by the European Union's Seventh Framework Program for research and technological development, and it was developed by 12 partners from 8 different countries, among them there were three water utilities, one university, one video game development company and some

[8] http://urbanwater-ict.eu/

governmental institutions. The project was seeking to develop and test an intelligent water management platform for the efficient and integrated management of water resources in urban areas (Urban Water, 2015). More in detail, the project aim was a 50% reduction of urban water waste over 5 years of operation. The platform provides tools to manage data coming from smart meters, process information to forecast water demand and water supply availability, detect leakages in the water supply network, support decision-making of water authorities and water distributors, and empower customers to reduce their water consumption. The project identified 7 enabling features to increase efficiency in water usage (Avila, 2015):

- Effectively estimate water demand in urban areas in order to efficiently manage water supply chains.
- Reduce waste of water and economic losses associated to leakages in the urban water distribution network.
- Smooth daily water demand daily peaks to allow distributors to save costs related to the management of urban water distribution networks.
- Guarantee efficient and secure computational data management based on smart grids' recent and upcoming deployments in Europe.
- Reduce operating and maintenance costs associated with water metering and billing in urban areas.
- Incentivize urban households to reduce their current consumption and soften the current European water demand peaks.
- Build effective partnerships and develop innovation synergies between equipment providers, ICT companies and water distributors.

The platform consists on several components (Broussel, 2015), the main one is the customer portal that offers consumption monitoring, consumption forecast, and billing access information. Besides these functionalities, the portal features a serious game, **Water Mansion** (Nielsen, 2015), which seeks to raise consumers' awareness about efficient water consumption and its relationship with economic savings. In the game users should execute a series of task involving day-by-day actions, such as washing their hands, cleaning the dishes or filling the swimming pool. Each of these actions increase the consumption and reduces the "gold" that the user owns. The objective is to learn how to reduce consumption to save more "gold". The users are awarded a certain amount of "green drops" if in a given period the consumption is reduced with respect to previous periods (Figure 15).

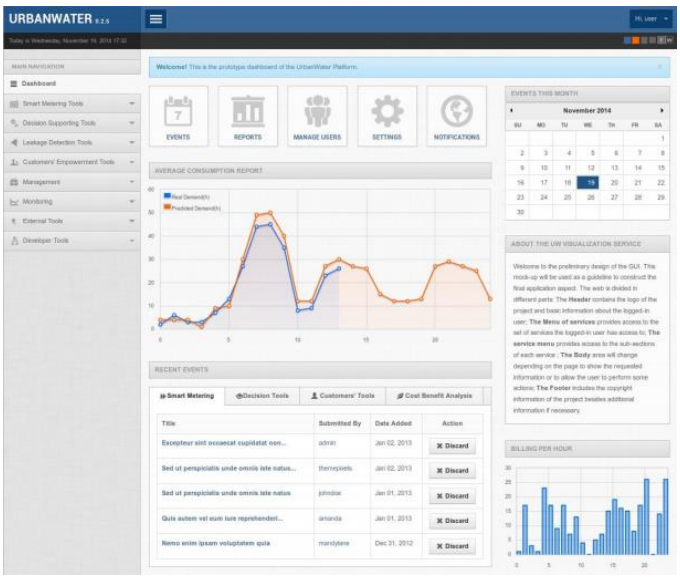

Figure 14: Urban Water Dashboard (Broussel , 2015).

Figure 15: Water Mansion, on the top left: the green drop and gold scores; on the center: the action tags (Nielsen, 2015).

4.3.8 WatERP project

WatERP[9] is another project funded by the European Union's Seventh Framework Program. It was developed and supported by the Staffordshire University, the technological center of Catalonia and other 7 technological and governmental partners. The project was focused on developing an "Open Management Platform" supported by real-time knowledge on the water supply and demand that enables an integrated and customized monitoring of the entire water supply distribution system, with the purpose of reducing the gap between water supply and demand through this information interaction and processing.

The project had two main objectives: an 8% water consumption reduction in water-scarce areas where water distribution is already efficient, and a 5% energy usage reduction in areas where the water is abundant and the distribution is efficient but the consumption of energy is high. Additional goals were the increase of user awareness and the promotion of behavioural changes of water utilities and authorities, (not end-consumers). From the technological point of view, the project aimed at identifying the key variables that must be monitored throughout the water supply distribution system to enable water supply and demand to be matched across the entire water supply network and while coping with water scarcity, drought and vulnerability indicators; and at developing protocols for real-time data collection and storage ensuring data quality, reliability and consistency. The WatERP architecture consists of three main components:

- the *data warehouse*, which manages the processing and storing of consistent, continuous and usable water supply and usage data originating from heterogeneous sources (periodically or in real-time);
- the *Decision Support System* (DSS), which coordinates actions prioritizing water usage, improving distribution efficiency and reducing costs;
- the *Demand Management System* (DMS), which analyzes socio-economical drivers and policies to improve the management of water demand.

Information from the whole supply chain (including e.g. water sources and deposits, desalinization plants, distribution networks) are stored in the data warehouse, which makes it available to the users in real-time (with the possibility of personalizing data analytics) in order to support their decision making, policy making

[9] http://www.waterp-fp7.eu/

and water pricing, risk management and planning processes (Chomat, 2013). Demand forecasting is performed by leveraging advanced data analytics that calculate similarity indexes between the consumption pattern of the current day and historical consumption data available in the database, identify the most similar ones, calculate weights to be assigned to similar days, and finally output a prediction of the demand for the desired future date.

4.3.9 Waternomics

Waternomics (Waternomics) is a project developed collaboratively by 10 institutions, including the national university of Ireland Galway, the UNESCO-Institute for Water Education, and the municipality of Thermi, in Greece. The goal of the project is to provide personalized and actionable information about water consumption and water availability to individual households, companies and cities in an intuitive and effective manner, at a time-scale relevant for decision making. Access to this information will increase end-user awareness and improve the quality of the decisions for decision makers in companies and in governments (Smit, 2015). The project aims to accomplish these objectives by combining water usage-related information from various sources and domains to offer water information services to end-users, supporting personalized interaction with water information services, conducting knowledge transfer from energy management systems to water management systems, enabling sharing of water information services across communities of users, and enabling open business models and flexible pricing mechanisms responsive to both demand and climate/environmental conditions. Additional project goals are the introduction of Water footprints (i.e., demand response and accountability) in the water sector; the interactive engagement of the consumers to enable efficient water consumption and behavioural change; the enactment of ICT-enabled water management by providing relevant tools and methodologies for water-related issues to corporate decision makers and municipal area managers. The Waternomics platform consists of a four-layered architecture:

- the *hardware layer* includes by the smart meters installed at various levels of the water distribution network, depending on the location site, (e.g. at appliance level for households and at building level public buildings or offices).
- The *data layer* stores, processes and analyzes the collected metering data to provide high level information reports (destined e.g. to municipalities).
- The *support service layer* implements the data analytics, the monitoring and alerting systems, and responds to the information requests from the application layer (Coakley, 2015).
- The *application layer* is designed as an application portal: it provides basic functionalities (or applications) and can be extended by getting more applications from a marketplace. Users access the marketplace, select the application they are interested in based on their role and the activities they want to perform, and install it. This approach ensures great flexibility in terms of personalization (Waternomics) and makes the portal customizable for a wide range of user types and location sites: administrators can decide which application should be available for each role and existing applications can be enhanced by adding components. Third party applications can also be made available through an API (Waternomics).

The applications are divided in 4 categories:

- *Monitoring*: Applications that allow users to monitor their consumption and have it visualized.
- *Learning*: Applications that provide educational and informative material to users.
- *Exploring*: Applications that allow users to explore the potentials of the dataspace in terms of analytics and related services.
- *Playing*: Gaming applications or applications with gamification elements that help users to learn and educate themselves through playing or through interacting with each other in non-leisure contexts.

The platform provides also a set of independent components, also available through the marketplace, which enable the user to create custom applications by combining them (e.g. to create dashboards). Some of the base applications for the household users are:

- *Family Dashboard*: Every family is entitled to create its own dashboard using a set of available components and choosing those that fit their needs. The total consumption component provides a visualization through a graph bar, the documentation explains that showing only cubic meters measurement might not be representative for most of the users, so it provides alternative representations like the number of kilograms of apples that could be produced with the same amount of water, or the amount of CO_2 that was released in the environment to deliver that amount of water to the household, thus enhancing awareness of the family water consumption (Figure 16).
- *Consumption timeline*: This component emulates the function of a social media timeline by presenting series of events in a chronological order. The points along the timeline represent disaggregate consumption events and provide comparison with previous week's events of the same type (e.g., washing-machine water consumption).
- *Notifications*: the user can set notifications preferences for each type if events, and receive alerts accordingly. For example, the users can set an alert when the total consumption of the month is 10% higher than the one of the previous month.
- *Drought conditions monitor*: This application periodically receives data from the European Drought Observatory [EDO] and informs the users about drought periods, thus raising awareness of water scarcity.

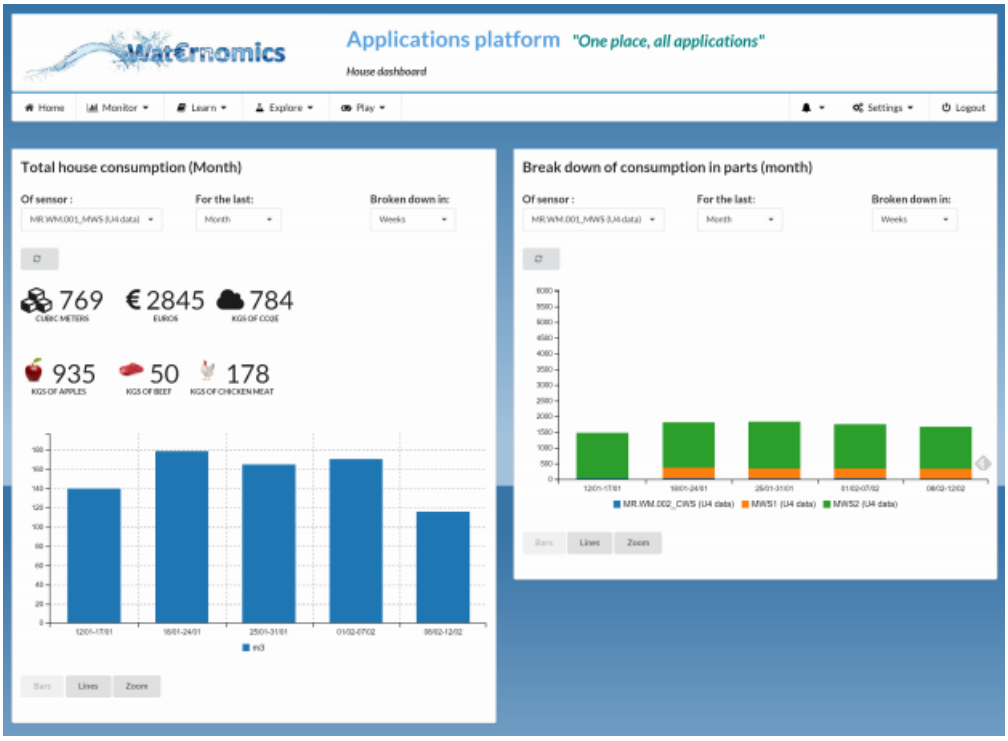

Figure 16: Family Dashboard (Waternomics).

For what concerns the game framework, the Waternomics platform (Waternomics) provides a leaderboard that shows the highest scores achieved by the users in the different game applications. The platform offers two games of trivia-like fashion. The first one is "Water Flavors": it asks the player to make educated

guesses about how much water is necessary to produce certain products. In case of correct guess, the player is awarded with points. This way, the game aims at creating awareness by educating the player about the importance of water in the production of food and other products of common use. The information used in the game is retrieved from the Water Footprint Organization[10].

The second game is called "Water saving calculator" (Figure 17): in the first stage, it provides a collection of water saving tips, in a second phase the player is asked to answer a set of questions by performing calculation based on the information provided by the tips. Players get points for the right answers and extra information for the wrong ones. The objective of the game is to make the players aware of the amount of water they are consuming and the potential savings that they can reach by changing some behaviours. As mention before, the architecture allows for the inclusion of additional games and gamified applications: the point storage and leaderboard management is achieved by an API.

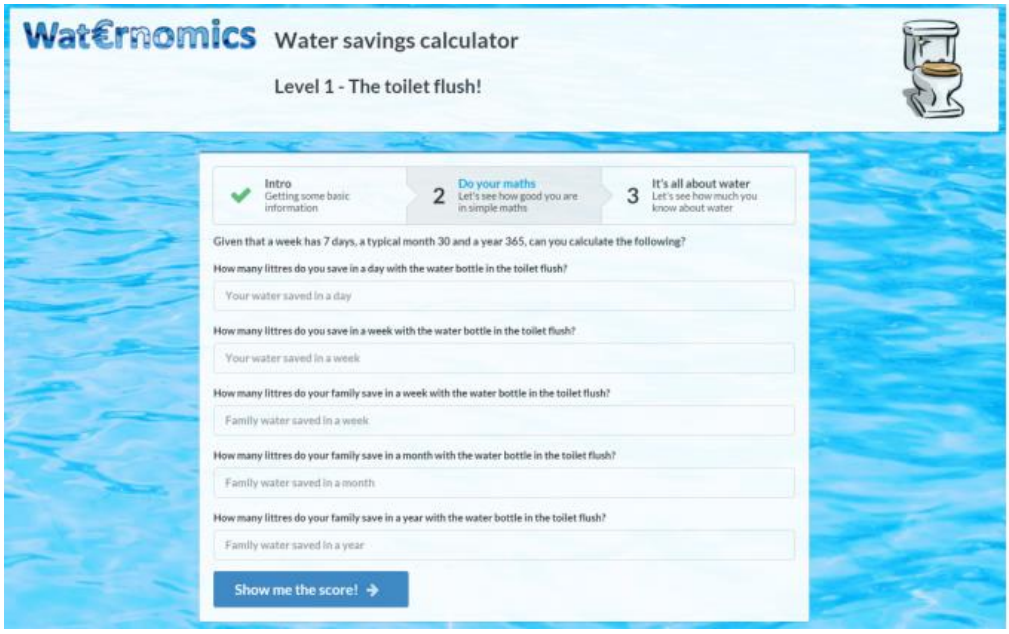

Figure 17: Water Savings Calculator (Waternomics).

4.3.10 SmartH2O

The SmartH2O project[11] was funded by the European Union's Seventh Framework Program for Research and Innovation. The project aimed at creating a communication channel and a continuous feedback-loop between water users and utility companies, providing consumers with information on their consumption in near real-time while enabling water utilities to plan and implement strategies to reduce or reallocate water consumption. This can be achieved by exploiting collected information about how the consumers adapt their behaviour as a reaction to different stimuli, such as awareness campaigns and changes in regulations or prices. To this aim, smart water meters were leveraged for collecting high frequency consumption data, which are used to provide high granularity information to water utilities on the state of the distribution network. At the same time, the collected information was employed to stimulate a change in water consumption behaviour. Accordingly, the SmartH2O system has been designed as a behavioural change support system (BCSS): "a socio-technical information system [...] designed to form, alter or reinforce attitudes, behaviours or an act of complying without using coercion or deception" (Oinas-Kukkonen, 2013).

[10] http://waterfootprint.org/.
[11] http://www.smarth2o-fp7.eu/

The SmartH2O approach considers that a change in water consumption behaviour can occur when underlying psychological determinants change through a combination of different incentive and persuasion strategies, acknowledging that both in the energy domain and in the water domain consumption data alone are not sufficient to induce a sustainable behavioural change (Fielding, 2013 and Nachreiner, 2015). Rather than relying on smart metered consumption feedback alone, the systematic approach followed by SmartH2O is grounded in motivational theory and research on incentive models, employing different mechanisms to incentivize users to save water. This has resulted in an ICT platform for improving consumer awareness, available on web and on mobile devices via a downloadable app. It incorporates smart metering, social computation, data visualization, big data analytics to model user behaviour, and gamification to engage consumers in the process.

As inducing long term behavioural changes is a challenging task that involves psychological, social and cultural factors, the project incorporates a mix of multiple engagement strategies. All actions undertaken by the consumer, in all the different applications (web portal, mobile app and even an educational game) are logged. Based on such action logs and on the metered consumption data, a gamified social game is performed in which consumers are encouraged to save water through a mechanism that assigns points, badges and prizes based on the full spectrum of their actions; leaderboards and weekly/monthly competitions provide a social dimension to the game and increase engagement and motivation to participate by creating a sense of community. Moreover, through the game the users are encouraged to provide detailed profile information about their demographics and their household configuration: such data are greatly valued by utility companies, as their analysis can provide important insights on the factors that drive the demand trends.

Figure 18 shows the home page of the Consumer Portal developed in SmartH2O. The page displays the histogram of the consumption readings collected with the smart meter infrastructure.

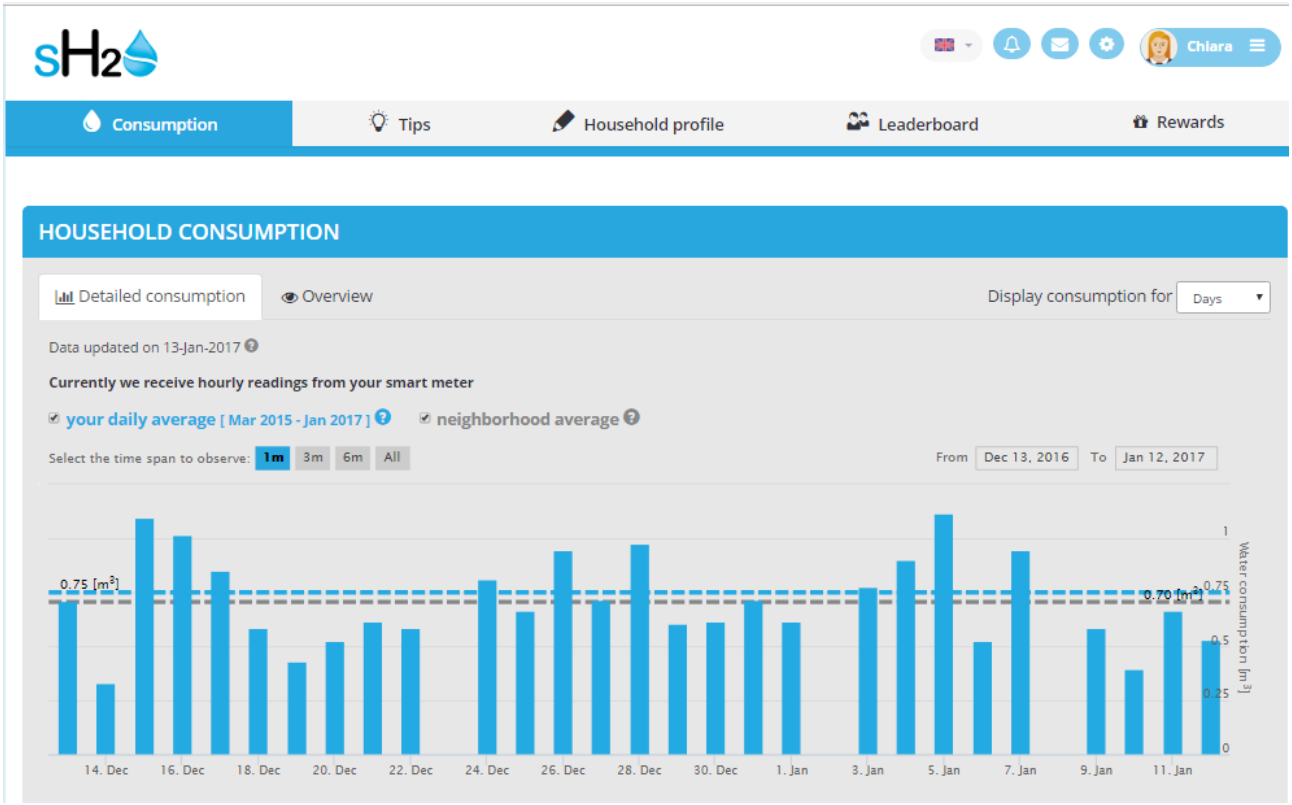

Figure 18: Home Page of the SmartH2O Consumer Portal

To improve the awareness and engage the user in a proactive water saving behaviour, a complementary interface visualizes consumption data in an alternative way, shown in Figure *19*.

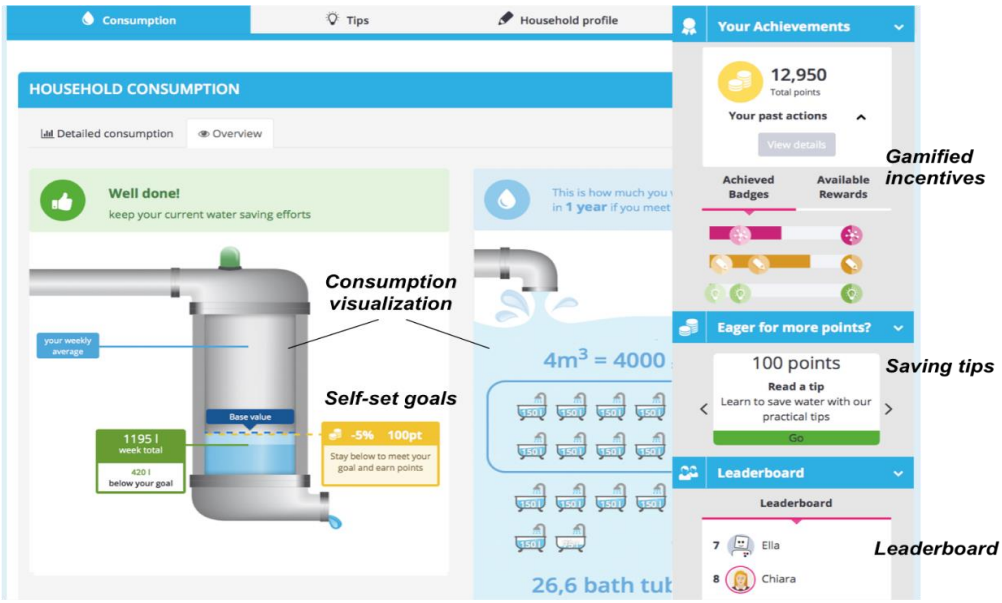

Figure 19: interface of the SmartH2O Consumer Portal showing an overview of the consumption progress

In the overview visualization, the progress of the consumption in a certain period, e.g., the current week, is displayed as a tank filling with water. The tank metaphor is the basis for further incentive model elements. As a complement to the utilitarian interfaces provided by the consumer web portal and mobile app, SmartH2O has also designed a water board game, called Drop! (show in *Figure 20*), with a digital extension, called Drop!TheQuestion.

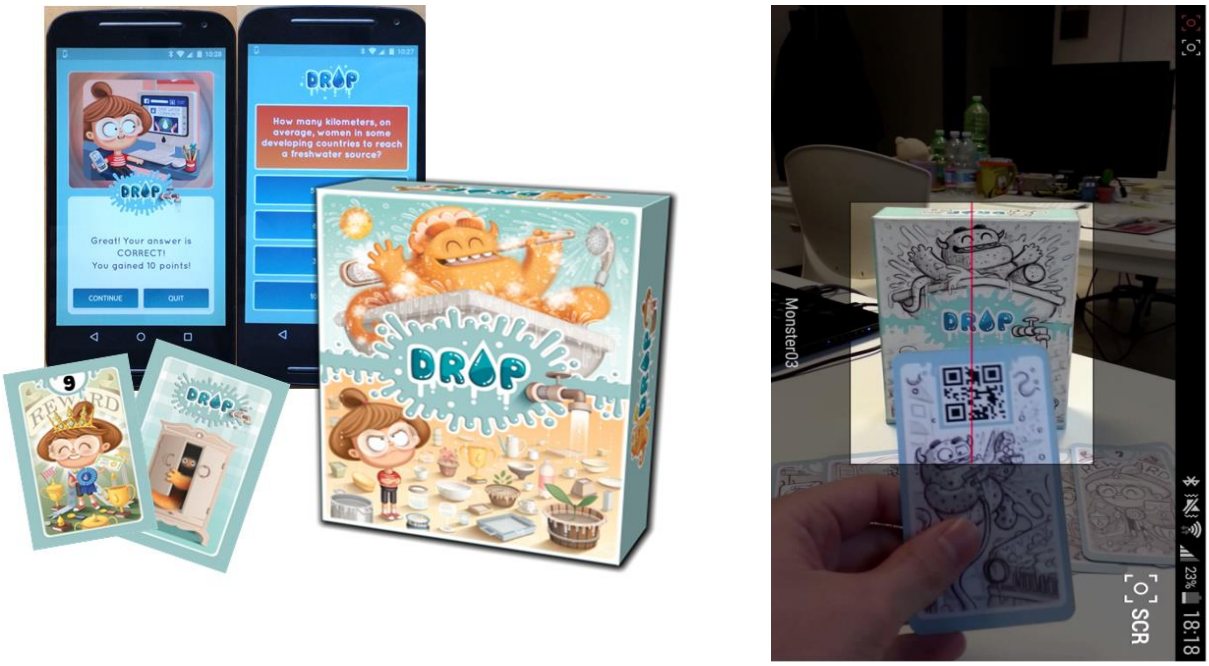

Figure 20: the Drop! board game and its digital extension (left); scanning a card with Drop!TheQuestion (right)

The Drop! board game is assigned as a reward to the users of the consumer web portal that achieve a minimum level of activity. It exploits a very popular home and family-oriented entertainment scheme, called “push your luck”. In this class of games, the players repeat an action (e.g., drawing a card) until they decide to stop, due to an increased risk of losing points or the next turn (e.g., drawing a negative card). The Drop! board game is designed around the basic idea that a game does not need to be educational. The game metaphor is simple yet engaging: Lily is a young and clever girl who wants to save water. Lily’s friend is a monster who does things in exactly the opposite way: the monster spills water (*Figure 20*). During the game, players do not need to answer questions or prove their knowledge to win, as is winning is determined by luck. The cards showing Lily are good cards and let the player score positive points, while the monster cards give players negative points. At the end of the game, players can transform the monster cards with negative points into positive points, by scanning a QR code on each monster card and answering a question received through their mobile phone or tablet (as shown in the right part of *Figure 20*). By playing the game within a household, saving water becomes a topic of conversation. This stimulates a water saving culture within the household, which in turn is a strong predictor of water consumption (Fielding, 2012). Playing the board game, and answering questions in the mobile app game increases knowledge. Users 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. Answering questions in the mobile game is awarded with points on the consumer portal.

4.4 Other Games with a Purpose for sustainability and sustainable consumption

Computer games, as a tool for computer-mediated behavioural change, create an immersive environment that can attract also kids and teenagers to serious topics and manifest a high persuasive potential. Moreover, games effectively exploit the procedural representation approach, i.e., a form of symbolic expression that uses processes rather than language to convey ‘how things work’ (Bogost, 2007). In well-designed games, players can combine the processes embodied in the game and create new interactions beyond those considered by the game designers. This paradigm introduces new ways to persuade the player, which match well with the rhetoric concepts exposed by Fogg in (Fogg, 2002) (triggers, motivation and ability) as the traditional means for persuasion through technology. Some recent contributions in environment and sustainability games focus on power conservation, environmental awareness, fossil energy use and water. Table 7 and Table 8 compare some persuasive games specific for energy and water management along their main distinctive features:

- Mechanics describes the type of the game.
- Roles list the roles assumed by the players.
- Players define the number of players that engage in a game round.
- Feedback specifies whether the game can interact with players during a round.
- Issues summarize the main problems highlighted by the game.
- Focus refers to the core persuasive/educational objective of the game.
- Target identifies a specific population of players targeted by the game.
- Data collection
- Platform specifies the technological environment/device for which the game is designed.
- Technology characterizes the implementation languages and frameworks.

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Table 7: Summary of sustainability games features. Games analyzed: eVIZ(Stone 2014), ecoPet (Yang 2012), Juoulebug[12], WeSpire[13], Plan It Green[14], Water wars (Hirsch, 2010), Atoll Game (Dray, Perez, LePage, D'Aquino, & White, 2005)

	eVIZ	**ecoPet**	**Joulebug**	**WeSpire**	**Plan It Green**	**Water Wars**	**Atoll Game**
Technology	Unity 3D		Android / iOS	Web / Android / iOS	Flash	N/A	VisualWorks and CORMAS platform
Roles	Residence Occupant / Family	Family	Family	Shareholders	Policymaker/ Mayor	Stakeholders	Family
Feedback	Continues Real Time feedback of the user actions over the environment	Tips, in-game alerts	Continuous feedback on money saved and CO2 reduction	In game alerts	No Feedback	Message	N/A
Mechanics	Simulation	Challenge Based	Achievements based on action fulfillment	Challenge Based	Simulation	Turn based	Rpg computer assisted
Issues	Energy Consumption Reduction	Raise awareness, and energy conservation	Sustainability and resource management	Resource Management	Energy Urban Planning	Policies, variable weather conditions	Policies, variable weather conditions, scarcity
Players	Single Player	Single Player	Single Player (Social competition)	Single Player	Single Player (Social Competition)	Multiplayer with chat	Up to 16 presential players
Focus	Domestic Energy preservation	Consumption and waste reduction	Energy & Water efficient use	Emission, energy, water, Waste & Fuel management	Energy efficiency & community wellbeing	Interaction among inhabitants	Land/water allocation conflicts
Target	Household Residents	Students / Young adults	Teenagers and young adults	Employees	Students	New Mexico residents	Tarawa atoll residents and policy makers
Platform	PC / Oculus Rift	PC	Mobile devices	Web and Mobile devices	Web	Web and mobile	PC supported board game
Data collection	Simulated Data	N/A	Connects with Utilities	N/A	N/A	Interviews	Semi-automatic software

[12] Joulebug https://joulebug.com/

[13] WeSpire http://www.wespire.com

[14] National Geographic's Plan It Green https://www.nationalgeographic.org/media/plan-it-green-big-switch/

Table 8: Summary of sustainability games features . Games analyzed(cont.): Catchment Detox (Science, 2014), FloodSim (Rebolledo-Mendez, Avramides, Freitas, & Memarzia, 2009) and Aqua Republica[15], Irrigania (Seibert 2012), Run the river[16], SeGWADE (Khoury 2016), Drop!TheQuestion (Fraternali 2015)

	The Basin Challenge/ Catchment detox	**FloodSim**	**Aqua Republica**	**Irrigania**	**Run the river**	**SeGWADE**	**Drop! The Question**
Technology	Flash	Flash	Unity	VisualBasic ASP.NET	N/A	HTML5 and WebGL	Java
Roles	Policymakers	Flood policy strategist	Mayor	Farmer	Decision maker	Water Distribution Systems managers	Water expert
Feedback	Messages in game and leaderboard	Messages in game	Messages in game	No feedback	In game alerts	Continuous and instant feedback to players	No feedback
Mechanics	Turn based	Turn based	Turn based	turn-based strategy game	Simulation	Model simulation	Trivia
Issues	Policies, variable weather conditions, scarcity	floods	Policies, variable weather conditions	Governance and management of common resources	Balancing water use between various water consumers	Water Distribution Systems design decisions	General water culture
Players	1-2 players	1 player	1 player	Single player	Single player		Single player
Focus	Manage a river catchment	Raising awareness on flooding policies	Conflicts and trade-offs in a river basin	Water sharing policies, water scarcity	Water management policies	Drinking Water Distribution Systems	Interesting facts on water and water consumption
Target	Teenage students	UK residents	Everyone	Students	Kids	Students	Family
Platform	Web	Web	Web (portable)	Web	Mobile phones and tablets	Windows, Linux, iOS and Android	Android mobile devices
Data collection	N/A	N/A	Numerical models (Mike Basin)	Discussion in class	Based on actual and modelled historic data	Feedback computed with hydraulic simulation engine based on EPANET	N/A

[15] "Acqua republica," [Online]. Available: http://aquarepublica.com/

[16] https://www.mdba.gov.au/education/students/apps

A very recent literature review for gamification and serious games, as applied in domestic energy consumption, is provided in (Johnson, 2017); the review examines 25 contributions involving different levels of gamification for behavioural change with respect to energy. The articles were classified by the type of gamification applied, the type of outcomes of the experiments, the data collection, data analysis and the size of the experiment, among others and given a quality assessment of the methodology used. The outcomes were classified as:

- Behavioural outcomes: Actual or intended behaviour taken by the participants within and outside the game.
- Cognitive outcomes: Affective and motivational factors and energy-related attitudes, engagement and awareness of energy conservation.
- Learning and knowledge acquisition outcomes: Gained knowledge of energy consumption, in example explicit knowledge of electrical appliances or identification of energy saving actions.
- User experience outcomes: Participant attitudes towards the applied game based on user satisfaction and usability.

The review shows that in most of the cases the outcomes are positive in all the categories, with only a few reported as mixes or negative, and concludes that there is evidence of positive influence of applied games (gamification and serious games) in domestic energy conservation, that includes not only actual consumption reduction, but behavioural change and increased awareness of energy efficiency.

Table 9: Summary of the outcome of the experiments review by Johnson et al (Johnson, 2017)

Outcome	Positive	Mixed	Negative	Number of times assessed
User Experience	20	0	0	20
Cognitive	12	3	0	15
Behavioural (real word)	9	1	0	10
Knowledge	6	2	1	9
Behavioural (in-game)	3	0	0	3

In summary, findings from existing literature suggest that gamification strategies and games with a purpose can be applied in sustainability context with a good user acceptance and successful results in savings (as supported by empirical studies such as (Rottondi, 2016)). However, the success depends on many factors, most of them related with the design of the incentive models and game mechanics motivating the usage of the systems and the specific system functionalities offered.

The most important points and lessons from the literature include:

- Providing real time and historical information of the consumption is important, but the data is useless if the consumer cannot associate meaning to it, therefore informative measurement should go along with the real data (e.g. presenting cost in terms of financial or environmental impact along with the consumption in cubic meters).
- Real-word rewards and prizes are a good strategy to keep user engagement, but it is important to select them according to the type of consumers. Having various prizes with different options seems to be an appropriate solution when the player population is diverse.
- Games are good influencers when trying to make changes in consumer behaviours, but permanent changes are difficult to achieve. The game mechanics should be powerful enough to keep the user

mind set, a good recommendation is to strongly relate the actions and points in the game with actions in the real world.

- People are now aware of the problems related with resources and are willing to change their behaviour, but constant, useful and interesting information about what to change and how to change it should be always available on demand and offered by the game.
- Designing systems that can successfully stimulate behavioural change requires a systematic modelling of the behavioural change process and its implementation through several types of incentives (virtual, physical, social) adapted to the characteristics of specific target user groups (Novak, et al., 2016).
- Social interaction and competition are powerful engagers and influencers of behaviour, they should be exploited but in some cases moderation might be required and evaluation should be made about the effort required in relation with the benefits.

4.5 ALGORITHMS FOR IMPLEMENTING GAMIFIED INCENTIVES

All the surveyed gamified applications and games with a purpose rely on a common algorithmic core, which we call **Gamification Engine**, for the translation of the behavioural signals coming from the users into behavioural change stimuli. These stimuli act on the user's awareness and promote a behavioural change process, which is retrofitted to the Gamification Engine and generate new stimuli, triggering a virtuous behavioural change loop depicted in Figure 21.

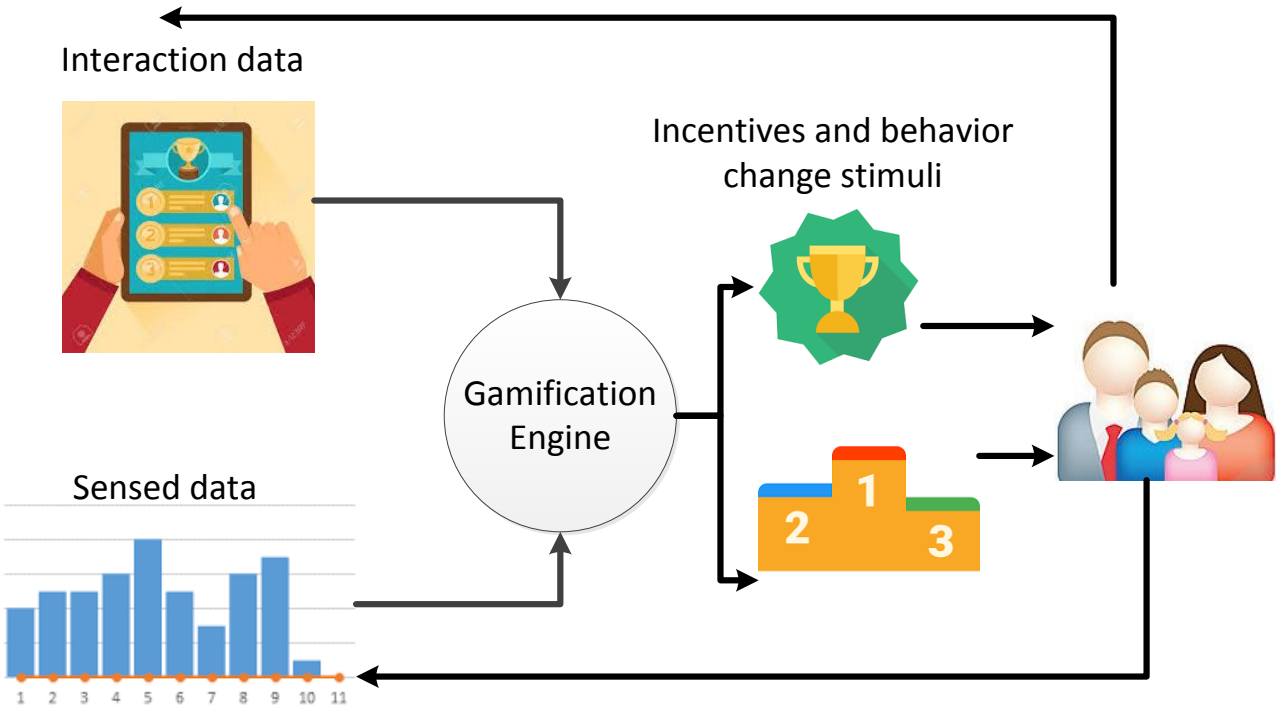

Figure 21: the Gamification engine as the algorithmic core of gamified behaviour change applications

The classes of data in input to the incentives algorithms embodied in the gamification engine can be broadly understood as belonging to two categories:

- **Interaction data**: these are data that record the interaction of the users, mediated by the (gamified) socio technical systems; they can comprise the variety of interactions mentioned in the

reviewed systems, ranging from the simple login or start of the application, to the accomplishment of articulated tasks in a task-based application or in a sustainability-oriented gameplay.

- **Sensed data**: these are objective data that come from the activity of the users in the real world. In the area of sustainable resource usage, such objective data refer mostly to **resource consumption**, as recorded by smart meters or manual input by the users into the system. In other types of persuasive systems, e.g., applications for promoting healthy lifestyles, they could represent user's activity traces (e.g., miles run, etc.).

The Gamification Engine "listens" to the user's actions and sensor inputs transforms them into a variety of incentives, for improving activity and participation. It usually works as a rule-based engine, which takes inputs and produces outputs as illustrated in Figure 21. 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 mapped into an incentive, such as a reward or the recognition of some goal attainment or other achievement. The architectural details and rules design for the gamification engine underlying gamified applications have been little exposed in scientific literature, with notable exceptions such as in (Codish and Gilad 2014, Herzig et al 2013, Galli et al., 2015; Novak et al., 2016).

The algorithms at the base of the enCOMPASS GE rely on a common set of concepts, which are exemplary for such systems can be summarized as follows:

- **Gamified User Interface:** the GUI for customers that allows to explore gamified objects
- **Monitoring Interface**: 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) can be grouped and organized in order to better reflect the different motivations of the users. Examples of such areas are: education, reputation, socialization and consumption.
- **Credits**: points that the user (player) can earn performing actions on the platform.
- **Action**: a rewarded task the customer can perform in the persuasive application (e.g., logging in or using the app, reading a tip, watching an educational video, inviting a friend to join the community of app users). Actions can be freely executable and always rewarded, or constrained: for example, actions could be rewarded only with a given frequency (e.g., only one login a day) or can be defined as non-repeatable (e.g., watching an educational video should be recognized only the first time the user sees it).
- **Goal**: measurable objectives (e.g., energy saving goals) that can be achieved by the user.
- **Badges**: virtual recognitions assigned to a user and visible to other users in the community, mostly used to demonstrate consumer status and progress. The GE algorithms must map actions to the badge they contribute to attain.
- **Reward**: physical item that can be redeemed by the user, as a consequence of achieving a determined amount of credits in the persuasive applications.

Most gamified applications and GWAPs group activity and engagement stimuli (e.g., user's actions and badges/rewards) in four broad thematic areas (see examples in section 4.3):

- **Resource saving**: refer to actual resource saving as metered by smart meters or declared by the user.
- **Resource saving Insights**: refers to learning how to save resource.
- **Engagement**: refers to activity in the persuasive applications and within the community of reference.

- **Profiling**: refers to data input about the usage context: household, office or building.

Across such areas, four major categories of actions are normally recognized and classified based on the source where they come from:

- **Consumption actions**: these actions derive from the smart meter readings or user's declared consumption. When the consumption data are received, they are elaborated to check that some of the resource saving goals has been achieved (e.g., reduction of x% over the baseline average consumption of a period, such as week, or month).
- **Application usage actions**: these actions are generated as consequences of the user activity in the Consumer portal.
- **Gameplay actions**: these actions are produced by a game with a purpose and correspond (e.g., correct answer to a energy or water trivia education game).
- **External actions**: these actions are produced by external applications, e.g., the pre-existing portal or business system of the water or energy utility.

The algorithms for action recognition and score assignment differ according to the source of the action and the synchronicity between the user's or smart meter input and the rule engine algorithm execution. For example, in a smart metered context, sensed data are typically 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 resource-metered users MU
If reading frequency >= day
    Compute new weekly average NWA;
    For all active weekly reslource saving 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 22. Abstract algorithm for synchronous weekly sensed data 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 executions' of the GE, according to the abstract algorithm of Figure 23:

```
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 23. Abstract algorithm for asynchronous user's action processing.

The algorithms of Figure 22 and of Figure 23 are parametric with respect to the values of the configuration of the gamification engine objects: actions, badges, and rewards. The value of the configuration parameters dictate how much each action is rewarded and which level of points is necessary to unlock a given achievement (e.g., the attainment of badge or reward); they must be fine-tuned based on the specific characteristics and sustainability objective in each scenario.

5 BEHAVIOURAL CHANGE INCENTIVES FOR SUSTAINABILITY CHALLENGES

The overview in the previous sections reveals that while there are many different types of applications and approaches to behavioural change for sustainability challenges, they share common incentive elements aiming at motivating and inducing a change in users' behaviour. Accordingly, this section summarizes the different types of user's actions and incentives of behavioural change applications, as found in the examples surveyed in section 4. These represent different types of specific engagement and incentive stimuli that can be used to instantiate the abstract incentive computation algorithm described in section 4.5. While section 5.1 presents findings from sustainability applications in research projects targeted to the general public, section 5.2 covers sustainability incentives specifically introduced in NGO's and professional practices, which will support the design of the enCOMPASS approach in public buildings and schools.

5.1 BEHAVIOURAL CHANGE INCENTIVES IN SUSTAINABILITY RESEARCH AND APPLICATIONS

This subsection summarizes incentives recommended in behavioural change applications from scientific literature and recent research projects targeted to the general household users, which will form the pillars for the design of the enCOMPASS system. This overview mainly focuses on the domains of energy and water saving as they are structurally similar and thus face the same challenges as in enCOMPASS (e.g. Micheel et al., 2014). Other sustainability areas such as transport have also been considered, mainly to provide examples of incentives that have not yet been covered much in the energy and water domain. Adding to this, section 5.2 then presents insights and incentives from non-academic practice.

A wide range of incentives has been found that can be clustered into the following classes:

- visualization and analytics of behaviour,
- comparison of behaviour against historical, normative, or social reference values,
- tips and recommendations,
- gamified incentives,
- social interaction,
- notifications and reminders.

As an overview, the table below summarizes the main incentive classes used in behavioural change applications and exemplary studies and projects investigating them. Each of these classes is explained in the following subsections with examples of corresponding studies and projects.

Table 10: Behavioural change incentives overview

Incentives	**Examples**
Visualization of behaviour	BeAware project; Fréjus & Martini, 2016; Froehlich et al., 2009; Froehlich et al., 2012; Gölz & Hahnel, 2016; Gustafsson, 2005; Gustafsson, 2009; Monigatti et al., 2010; Novak et al., 2016 (SmartH2O project); Rist, 2014; Sundramoorthy et al., 2010 (DEHEMS project)
Comparison of behaviour (e.g.,	Foster et al., 2010; Froehlich et al., 2012; Novak et al., 2016; Rist,

historical, goal, normative)	2014; Sundramoorthy et al., 2010
Action tips and personalized recommendations	De Luca & Castri, 2014; ENTROPY project; Jacucci, 2009; Gamberini et al., 2011; Novak et al., 2016; Peham et al., 2014; STEP-BY-STEP project; Sundramoorthy et al., 2010
Gamified incentives and serious games and serious games	Angelo et al., 2012; Centieiro et al., 2011; Doucet & Srinivasan, 2010; Ecker et al., 2011; emPOWER project; Gamberini et al., 2011; Gustafsson, 2009; Hirsch, 2010; Linder & Ju, 2012; Novak et al., 2016 ; Urban Water project; Waternomics; WatERP; *See also section 4.4.1-4.4.5*
Social interaction	De Luca & Castri, 2014; Foster et al., 2010; Gabrielli et al., 2014; Gamberini et al., 2011; Grevet et al., 2010; Jacucci et al., 2009; Mankoff et al., 2007; Novak et al., 2016; Peschiera et al., 2010
Notifications and reminders	Gabrielli et al., 2014; Kaptein & van Halteren, 2012 *See also section 3.4*

5.1.1 Visualization of behaviour

One key strategy for incentivizing behaviour change is the visualization of behaviour, e.g. providing energy consumption feedback in the energy domain, which allows users to self-monitor their energy saving achievements. Often, this information is provided interactively in the application (e.g. Novak et al., 2016), or as periodic reports that are sent to users (e.g. Mitchell et al., 2013 (WaterSmart); STEP-BY-STEP project). Visualizing the behaviour and providing the user with means to analyze it is a first step towards making the user more aware of their behaviour and ultimately changing it for the better (Tiefenbeck, 2014).

Visualizations can be data-oriented, e.g. bar or pie charts (Froehlich et al., 2012; Monigatti et al., 2010), closely connected to the real behaviour context, e.g. floor plans when showing resource consumption in a building (Monigatti et al., 2010; Froehlich et al., 2012), metaphorical, e.g. traffic lights and gauges (Monigatti et al., 2010; Rist, 2014; Sundramoorthy et al., 2010), playful and ambient such as shown in the BeAware project (2011) or Gustafsson (2005), and connected to nature or animal habitats, often termed eco-visualization (Froehlich et al., 2009; Gustafsson, 2009; Mankoff et al., 2010; Rist, 2014). Figure 24 shows examples of a bar chart, eco-visualization and gauge metaphor to present visual behaviour feedback.

To visualize behaviour effectively, e.g. resource consumption behaviour, and facilitate long-term sustainable behaviour change, the information on the behaviour to be visualized should be broken down e.g. temporally, by events, per appliance or type of behaviour (Froehlich et al., 2012; Gustafsson, 2009; Jacucci et al., 2009; Rist, 2014). Independent of how behaviour is visualized, it is key to present the information in an understandable way and seamlessly embedded into user's context – offering details and comparisons based on the current user context and activity situation (e.g. Fréjus & Martini, 2016). Closing this loop effectively in a user-friendly way is still a challenge.

Figure 24: Top left: Bar chart visualization (Novak et al., 2016), Top right: An eco-visualization of energy consumption: flowering garden indicates consumption below average (Rist, 2014), Bottom: Gauge metaphor visualization (Sundramoorthy et al., 2010).

5.1.2 Comparison of behaviour against historical, normative, or social reference values

When visualized, behaviour is mostly shown in comparison to a reference value or benchmark, e.g. a historical, goal or social reference. Such references or benchmarks enable the user to better understand whether their behaviour is "normal", excessive, or economical (Rist, 2014). Different references enable different comparisons, e.g. historical references for self-comparison, normative references for comparison with other households or individuals and 'social' comparison for comparison against others (Froehlich et al., 2012; Foster et al., 2010). Goals as a reference for comparison can be provided by the system, or set and adjusted by users themselves (e.g. SmartH2O; Froehlich et al., 2012). In their design probe study, Froehlich et al. (2012) found that goal-comparison was most valued for self-set consumption goals, and least for goals set "top-down" by suppliers or local governments. Recently, mixed approaches have been tested, and proven to be effective: a system-set goal that can be adjusted by the user, according to his level of ambition and to his/her opportunities for energy saving (Gölz & Hahnel, 2016, Novak et al., 2016), whereby the default goal that is preset by the system is a crucial factor in the decision of the user which goal to set. This suggests that designers can influence the targets users set for themselves, by providing moderately ambitious goals the users perceive as a challenge.

Although some controversy exists whether social comparison (Foster et al., 2010) or historical comparison (Jacucci et al., 2009) of consumption performance have a greater effect on users, sustaining their interest and motivation once their performance is high (response-relax effect) is an open challenge (Jacucci et al., 2009; Gamberini et al., 2011; Peschiera et al., 2010). Figure 25 illustrates different examples of comparison of consumption.

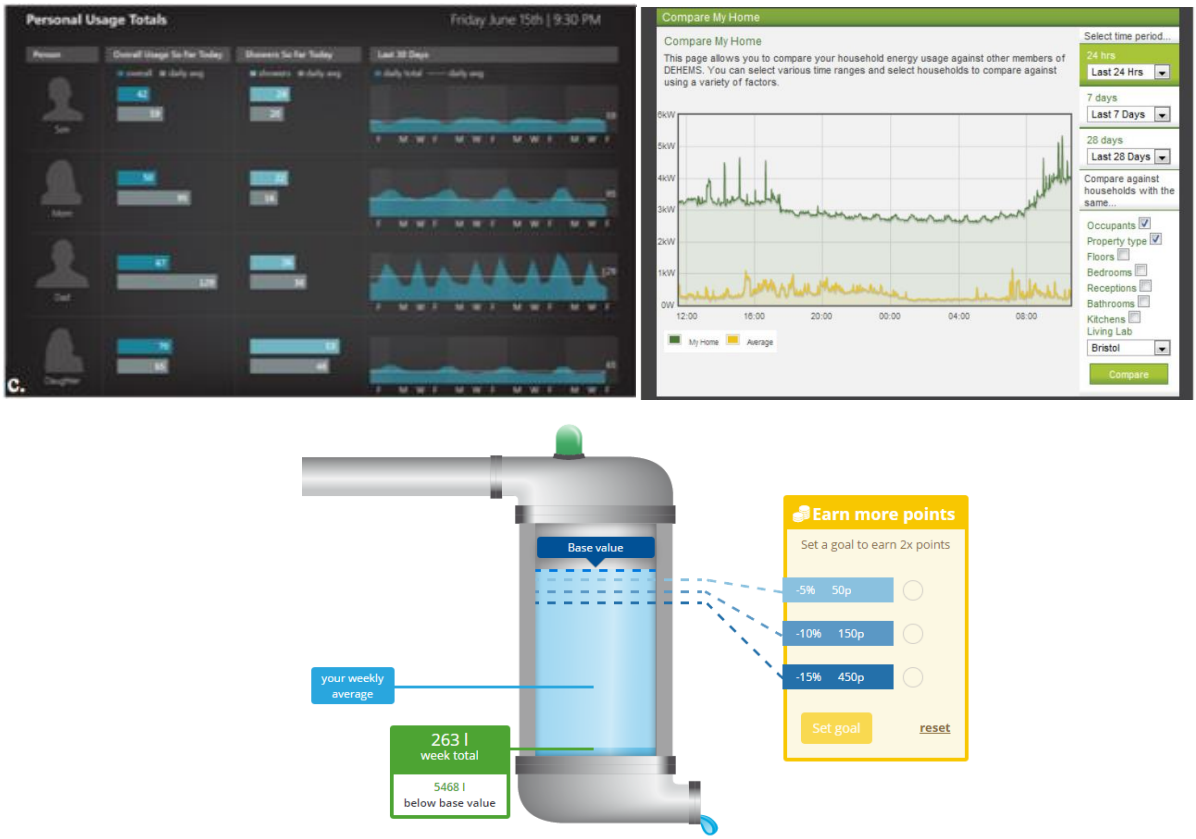

Figure 25: Top left: Social comparison (Froehlich et al., 2012), Top right: Comparison of consumption against different household types (Sundramoorthy et al., 2010), Bottom: Goal comparison (Novak et al., 2016).

5.1.3 Action tips and personalized recommendations

In most cases, tips are also provided to show users how to change their behaviour (Jacucci, 2009; Peham et al., 2014; Gamberini et al., 2011; De Luca & Castri, 2014; Sundramoorthy et al., 2010), sometimes provided in a contextualized but not in a personalized manner (Jacucci, 2009; Gamberini et al., 2011). More recent approaches also investigate personalized recommendations, using complex machine learning techniques of different complexity, to be able to present users tips and recommendations that are personalized to their context and specific behaviour: E.g., the STEP-BY-STEP project is exploring personalising recommended actions to suit the household profile and the activity history but not adapted to current activity context and not considering collaborative aspects. Also the ENTROPY project aims at providing users with recommendations to motivate behaviour change towards a more energy efficient lifestyle. The DEHEMS project also personalized recommendations e.g. based on household size, to the extent that users get information such as if they are consuming as much as a household their size, significantly more or less (Sundramoorthy et al., 2010). Figure 26 shows how behavioural change tips are considered in different applications.

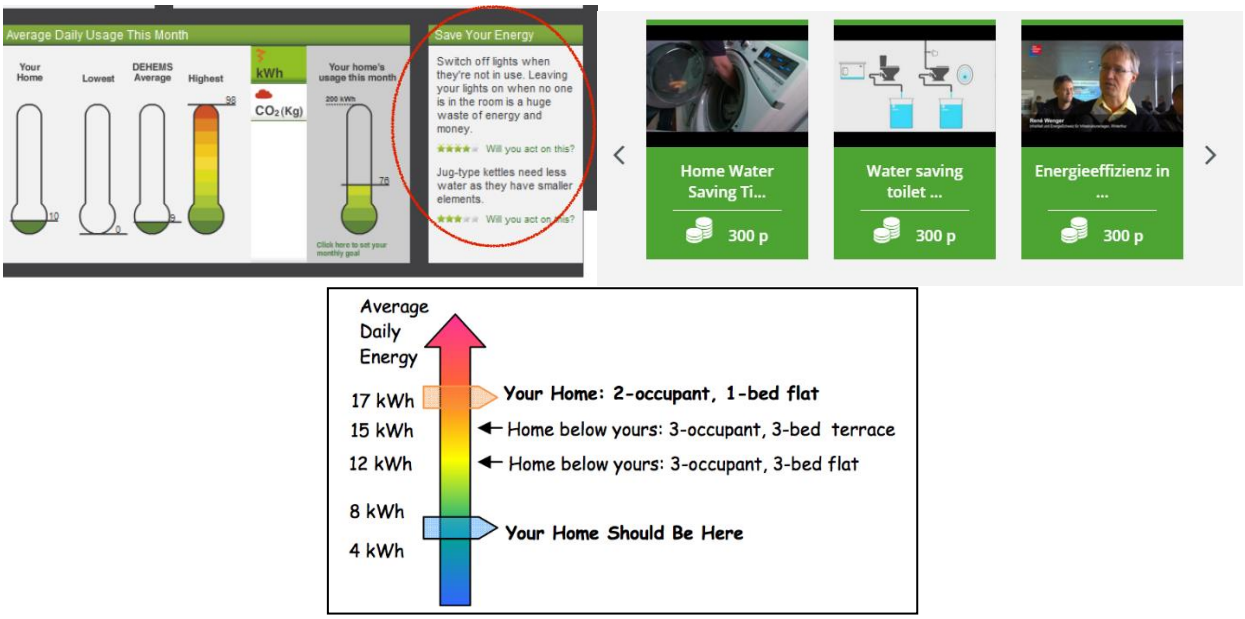

Figure 26: Top Left: Energy saving tips (Sundramoorthy et al., 2010), Top Right: Bottom: Water saving tips in SmartH2O (Novak et al., 2016), Bottom: Example of feedback based on household profiling (Sundramoorthy et al., 2010)

5.1.4 Gamification incentives and games with a purpose

As detailed in section 4, gamified incentives and GWAPS are also a promising tool for computer-mediated behavioural change. We consider gamified incentives and games here briefly, too, to give a complete overview of applied incentives. Embedding a behavioural change application in a gamified context means e.g. that users can earn points for their actions and get rewards, either virtual, e.g. badges, or real-world rewards, e.g. discounts or gadgets. Taking this approach further, some create actual games to incentivize users. The status of the art of persuasive games and applications, as described in the recent literature (between 2009 and 2017), includes various applications and games in different sustainability areas, such as: energy conservation (Doucet & Srinivasan, 2010; Gamberini et al., 2011, Gustafsson, 2009), environmental awareness (Centieiro et al., 2011; Angelo et al., 2012; Linder & Ju, 2012), fossil energy use (Ecker et al., 2011) water (Hirsch, 2010) and transport (emPOWER [17]project, 2017). E.g., SmartH2O (Novak et al., 2016), the water behaviour change project at the base of EnCOMPASS, has developed a board game and mobile trivia app on water sustainable consumption, and applied gamification to their main water saving application, the SmartH2O portal.

5.1.5 Social interaction

Social interaction means are used to motivate users to change their behaviour. Two classes of approaches can be distinguished: competitive and cooperative (Grevet et al., 2010; De Luca & Castri, 2014). According to e.g. De Luca & Castri (2014), competitive and cooperative approaches can foster better behaviour. Competitive approaches are often gamified, and include e.g. leaderboards that rank users (e.g. Gabrielli et al., 2014; Foster et al., 2010), sometimes even introducing prizes at the end of a competition period (e.g. SmartH2O).

Cooperative approaches are not so common yet. E.g., Grevet et al. (2010) focused on how social feedback can encourage individuals to have a social impact such as increasing their green actions. They developed a social visualization interface, in which e.g. different city districts must work together to uncover a kind of

[17] http://empowerproject.eu/about-empower/

puzzle of a familiar view of the city, in which clear squares are high performers, while dark squares have few participants saving energy. The more districts engage, the most visible the image. In a small first study by Grevet et al. (2010) of a dorm competition at a small college (Figure 27), which used the visualization adapted for the dorm setting, the trend suggested that the addition of social information may lead to increased participation in the site.

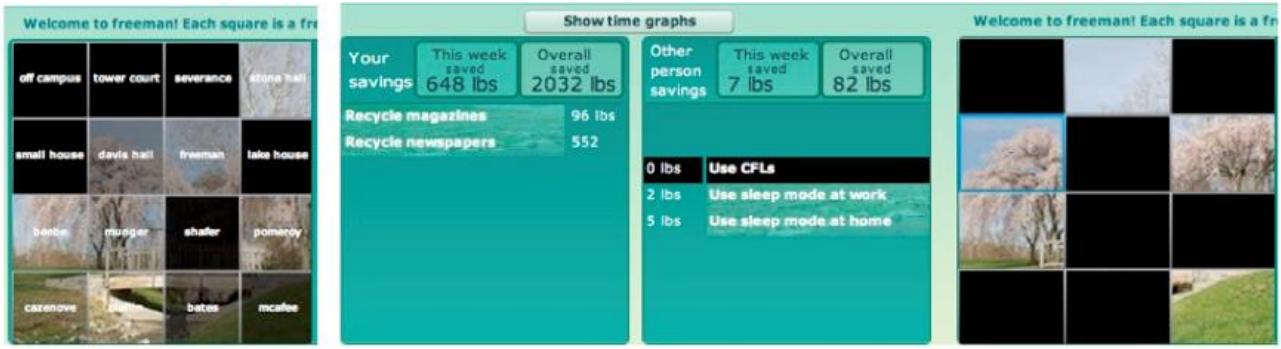

Figure 27: Cooperative social visualization (Grevet et al., 2010)

Rather than incorporating social aspects into new behavioural change applications, existing social networks have also been leveraged. E.g., Mankoff et al. (2007; 2010) and Foster et al., (2010) incorporated energy consumption feedback into existing popular social networks. Figure 28 shows applications that have been incorporated existing into social networks. However, among other things, in their 2010 study, they showed that creating internal support for social interaction within a native behavioural change application was needed rather than making use of existing social networks. Another approach is to enable the sharing of achievements from the SmartH2O platform on existing social networks, e.g. provided by the SmartH2O project (Novak et al., 2016).

Figure 28: Left: MySpace / Facebook plugin (Mankoff et al. 2010), Right: Facebook app with friend comparison (Foster et al., 2010)

5.1.6 Notifications and reminders

While much research has studied attention triggering in general, e.g. when the right "opportune moment" is to disturb users with a proactive message (see section 3.4), less has been done to investigate the use of notifications and reminders to incentivize behaviour. As one example, Kaptein & van Halteren (2012) have explored the means of adaptive persuasive messaging to increase service retention, by using persuasion

profiles to increase the effectiveness of email reminders. In their study, Kaptein & van Halteren (2012) showed that a main benefit of the persuasion profiles was a lower dropout rate of the service.
In a small study, Gabrielli et al. (2014) investigated weekly personalized notifications to encourage sustainable travel choices, according to their profile and travel behaviour, which were derived from usage logs. Notifications e.g. concerned invitations to consider carpooling with colleagues for commuting purposes (Figure 29). Results indicated that "personalized notifications were not effective in changing user behaviour in the short term, but contributed together with social and individual motivational strategies to improve user attitudes and behaviour for sustainable mobility in the longer term" (ibid.).
However, these examples do not yet provide sufficient detail about user acceptance and design issues, in terms of acceptable and effective frequencies of sending notifications, the content of the notifications, or the design challenge of attracting attention to the notification amidst the abundance of other notifications.

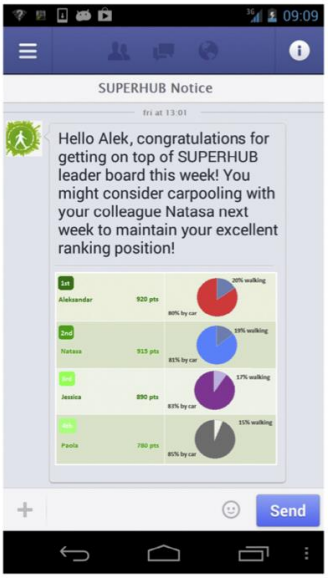

Figure 29: Example of personalized notification sent through the Facebook account on the mobile app of the user (Wizard of Oz) to encourage carpooling with colleagues, showing also leaderboard of participants points achieved that week (Gabrielli et al. 2014)

5.2 BEHAVIOURAL CHANGE INCENTIVES IN NGO'S AND PROFESSIONAL PRACTICE

A lot of actors from the non-academic-world are working on energy efficiency and energy savings when addressing climate change mitigation. In these approaches, individuals are addressed through different behavioural change interventions and incentives, such as knowledge transfer and guidance, self-efficacy, rewards, or promoting best-practices. The following sections highlight several examples representative for these different strategies.

5.2.1 Environmental education

From childhood on, most people learn and define fundamental views and thoughts which shape them for the whole live. Education starts in early childhood and continues all through life. The main aim of environmental education at the grassroots level is to succeed in making individuals and communities understand the complex nature of the natural and the built environments. Further, to acquire the knowledge, values, attitudes, and practical skills to participate in a responsible and effective way in anticipating and solving social problems, and in the management of the quality of the environment. Objectives of the environmental education are:

- **Awareness**: To help the social groups and individuals to acquire knowledge of pollution and environmental degradation.

- **Knowledge**: To help social groups and individuals to acquire knowledge of the environment beyond the immediate environment including distant environment.
- **Attitudes**: To help social groups and individuals to acquire a set of values for environmental protection.
- **Skills and Capacity Building**: To help social groups and individuals to develop skills required for making discriminations in form, shape, sound, touch, habits and habitats. Further, to develop ability to draw unbiased inferences and conclusions.
- **Participation**: To provide social groups and individuals with an opportunity to be actively involved at all levels in environmental decision making.

These objectives are in line with the psychological determinants of energy consumption behaviour that are commonly targeted in academic behavioural change studies (see also *D5.1 Behavioural change models and determinants of energy use*).

In kindergarten children can learn the importance of energy efficiency and a sustainable way of handling energy resources and natural resources. Beside the curricular environmental education many organisations are engaged in environmental education. For example the youth organisation of environmental organisations like WWF, Greenpeace and NABU perform different events. From specific projects in kindergartens and schools, over summer camps to marches the NGOs educate young people.

Figure 30: a) Greenpeace Youth campaign "Our Climate. Our Future. Your Decision." b) Children meet amphibians in a nature conservation station. (Photo: Sonja Heuner)
Source: https://www.greenpeace-jugend.de/index.php?pg=2&s=kampagnen

The NAJU (Youth Association for the Protection of Nature), for example, is the independent youth division of NABU. With over 75,000 members, NAJU is Germany's largest young people's organisation for extra-curricular environmental education, environmental protection and practical conservation work. By allowing young people to experience nature and to play a part in practical nature conservation and in shaping environmental policy, NAJU is helping to pave the way towards a sustainable society worldwide for current and future generations of young people. The Youth Association keeps a critical eye on environmental policy developments, giving young people a voice and encouraging them to take part in debates, projects, campaigns and to make political demands. The organisation acts responsible, setting an example for sustainable consumption and lifestyle.

One prominent project by NAJU is “Klasse Klima”. Young volunteers all over Germany and in cooperation with other NGOs work with children at the age of 10-15. Aim of the project is to motivate pupils to live climate friendly and sustainable and teach them the skills for that.

But since learning is a life-long process, environmental education for adults is not less important. Adult environmental education is very important to reach the UN Sustainable Development Goals SDGs and the climate targets. Adults can be educated voluntarily when they visit an exhibition or a museum. They can engage themselves in groups or organisations. They can use literature and the internet for themselves, or at work they can take part in obligatory or voluntary educational programs.

NABU operates more than 100 nature conservation centres all over Germany. The centres can be used for events (in sustainable or nature conservation context) and they can include exhibitions for nature conservation, sustainability or energy efficiency etc. Finally they provide the objectives of environmental education. The NABU-Centre “Blumberger Muehle”, for example, has a strong focus on “Education for sustainable development”. They offer individual nature experience, adventure and self-efficacy to build up a strong emotional and sustainable relation to nature, especially for children and teenagers. Its education strategy brings insights in ecological, economic and sociocultural systems and their interactions.

A different approach to the environmental education follows the project “fifty-fifty”. Pupils can save energy in school due to the change of their user behaviour. The idea is: At the end of the school year the pupils “earn” half of the save energy costs. This approach motivates the pupils to save energy and shows the responsibility for energy saving and efficiency.

Figure 31: Fifty-fifty project in Berlin
Source: http://www.fifty-fifty.eu/projekte/reinickendorf.html

Figure 32: Fifty-fifty project in Markranstädt
Source: http://www.fifty-fifty.eu/projekte/reinickendorf.html

Selected examples

Name	Topic	Country	Link
Study Environment and Development with The Open University	Academical education for Environment and Development	UK	*http://www.openuniversity.edu/welcome/study-environment-and-development-with-the-open-university*
Fondation de France	Philanthropic network	France	*https://www.fondationdefrance.org/en/environment-education*

Zeleniosijek	Bilingual environmental education in Drava Basin	Hungary	*http://www.zeleni-osijek.hr/projekt/bilingual-environmental-education-in-drava-basin/?lang=en*
Children's Environmental School	directed towards school and improving educational system. CES fulfils its mission by promoting incorporation of environmental education into school.	Latvia	*http://videsskola.lv/about-us?showall=1*
School of Sustainability	empower people to mobilize, resist and transform societies and create a just world	Worldwide	*http://www.foei.org/what-we-do/school-of-sustainability*
Croatian Business Council for Sustainable Development	contribution to better understanding and implementation of sustainable development	Croatia	*https://www.csreurope.org/croatian-business-council-sustainable-development*
Summer School	The main goal is to fill education for sustainable development with life and to further help foster school kids to tackle all problems and challenges of our globalized world.	Austria	*http://www.umweltbildung.at/english/initiatives/summer-school.html*

5.2.2 Guidance and Consultation

To change behaviour towards a more sustainable society, several offers of guidance and consultations are available. In opposite to education measures guidance and consultation measures are most often very specific and rather pull-communication. In the academic world the idea of "windows of opportunities" for behavioural change is diffused into practice. For instance energy efficiency guidance leaflets can be found in municipalities where people have to go after moving. Also a specific and personal consultation in energy efficiency and saving is offered by some German local communities for new citizens or those with low income who pay a big share for energy costs. Best-practice examples are widely used in guidance leaflets, so readers get an easy to understand example of how an issue could be addressed in perfect way.

Several organizations are giving guidance and consultations either because they are commissioned by someone or to fulfill their own mission. NABU for instance though not commissioned to consult and guide the public in terms of sustainable behaviour has a variety of flyers for promoting sustainable lifestyle.

Figure 33: NABU flyer to promote the usage of green electricity ("Switch now to green power – Tips for the right utility choice")

In total NABU has eleven so-called "*NABU-Tipps"* tip-giving guidance on several behavioural issues for consumers (despite a vast amount of information and flyers for other specific target groups). The structure of those flyers is similar: explaining the subject and why a certain behaviour is problematic, explaining side effects, giving a best-practice example and finally giving tangible and usable tips to help an individual to significantly change its behaviour. Those flyers are available online for download and also printed in federal NABU-offices and at NABU-events.

It is hard to evaluate, if a specific guidance or consultation offer is resulting in behavioural change. Apart from behavioural change, those offers are also commonly employed by several stakeholders also to build or extend relationships with customers and/or members.

Selected examples

Name	Topic	Country	Link
CO2_online	Advice and all information about heating energy saving, energy saving, modernization & building, subsidies and climate protection.	Germany	*http://www.co2online.com/*
Global Stewards	Green Eco Tips for Sustainable Living	Worldwide	*http://www.globalstewards.org/ecotips.htm*
G Adventures	10 Tips for Sustainable Travel with Kids	Worldwide	*https://www.gadventures.com/blog/10-tips-for-sustainable-travel-with-kids/*
FLORADATA	consulting company specialized in biodiversity, ecology, environment and natural resources, with a client-focused approach	Portugal	*https://www.environmental-expert.com/companies/floradata-46316*
SUST4IN	The key purpose is to support sustainability journeys through high quality and innovative information, consulting, training and assurance solutions delivered where they are, when they need it and in their languages.	Spain	*https://www.environmental-expert.com/companies/sust4in-79586*

5.2.3 Rewards and prizes

Another widespread strategy for promoting a sustainable lifestyle is giving incentives that go beyond the merits of saving energy. An incentive can be a contest, an award, a sponsorship, a mix of those instruments, or something comparable. The idea about giving incentives is people need to be motivated to change their behaviour beyond the actual benefit (here in energy saving).

As an example, in Berlin a lot of schools are participating in a competition called *fifty/fifty* where several incentives are combined. Classes are competing against each other; the more energy is saved the better. The best class is rewarded with half of the saved energy cost they can use for special activities, which is the reason for the name of this competition.

This special project also combines giving rewards with environmental education, as energy saving is becoming part of school teaching. A baseline of the energy usage and cost is to be defined and then measures for saving energy are identified. In cooperation of pupils, teachers and caretakers energy saving

measures are planned and carried out. In proportion to the difference with the baseline the respective part is then paid to the class account.

In the non-academic world the idea of giving an extra reward for behavioural change is due to the idea that people with different mindsets respond to different stimuli. Therefore to reach a bright variety of different target groups to change their behaviour towards more sustainability, a mix of rewards needs to be offered.

Selected examples

Name	Topic	Country	Link
Sustainability Award	The Austrian Sustainability Award is an integral part of the Austrian Strategy for Education for Sustainable Development and puts sustainability on the agenda of all Austrian universities.	Austria	*http://www.umweltbildung.at/english/initiatives/sustainability-award.html*
Education Support Fund	The fund promotes school education projects that deal with environment and sustainability.	Austria	*http://www.umweltbildung.at/english/initiatives/education-support-fund.html*
climate-kic Climathon	Climathon is a global 24-hour climate change hackathon which will take place simultaneously in major cities around the world on 27 October 2017.	Worldwide	*https://climathon.climate-kic.org/*
ENVIRONMENTAL, SOCIAL AND SUSTAINABILITY AWARD BY CIJ ROMANIA	Most sustainable buildings	Romania	*http://www.ozonehomes.ro/news/ozone-homes-is-awarded-with-the-environmental-social-and-sustainability-award-by-cij-romania*
Swedish Business Awards	The Swedish Business Awards is annually presented to companies registered in Estonia, Latvia and Lithuania that have demonstrated innovativeness, outstanding business achievements and contributions to society and environment.	Estonia, Latvia and Lithuania	*http://www.business-sweden.se/en/Trade/international-markets/europe/Lithuania/activities/business-award/*
SKANSKA	Sponsoring and CSR	Slovakia	*http://www.skanska.sk/en/about-skanska1/sustainability/social-responsibility/sponsoring-and-csr/*
Ekoland Innovation Award	Rabobank is involved in many initiatives to make the Dutch agricultural sector more innovative and sustainable.	Netherlands	*https://www.rabobank.com/en/about-rabobank/in-society/sustainability/articles/2016/rabobank-contributes-to-making-the-netherlands-more-sustainable.html*

5.2.4 *Self-efficacy*

”I hear and I forget. I see and I remember. I do and I understand.“ (Confucius). This 2500 years old citation is everlasting. The discovery, reflection, experience and performance by yourself – the individual concern - is the best way to understand and to evolve responsibility. In this sense, events that provide and enable self-efficacy are considered as a powerful instrument to influence the human behaviour for sustainability issues.

Nature excursions and travels on foot show the beauty and the value of the nature. Other good examples for self-efficacy are events like “International Coastal clean-up day”, which NABU and NAJU are supporting. One day a year all over the world people come to the sea, lakes and rivers and collect litter and waste. In 2016 nearly 12 million people and counting have been part of the world’s biggest volunteer effort to protect the ocean.

Figure 34: Left: Statistics of the International Costal Cleanup Day 2016; (Source: https://oceanconservancy.org), Right: Impressions from the International Costal Cleanup Day 2016 from the Baltic Sea. (Photo: Felix Paulin)

Selected examples

Name	Topic	Country	Link
Ecotourism	Combining adventures and nature conservation and fair trade.	Sweden	*https://www.thegreentrails.com/about-us/ecotourism/*
Nature trips	Sustainable Travel and Ecotourism	Slovenia	*http://www.nature-trips.com/en/about-us*
Sustainable Tourism	Sustainable tourism	Ireland	*https://vagabondtoursofireland.com/sustainable-tourism-ireland/*

5.2.5 *Legal framework*

If there is no economic or social motivation for sustainable development, often only the legal framework can provide the right soft spots. Incentives and prohibitions provide the necessary framework for sustainable development. The changes in behaviour for sustainability are then defined and implemented. The statutory requirement for sustainable behaviour should and can only be implemented if all other measures have not led to success.

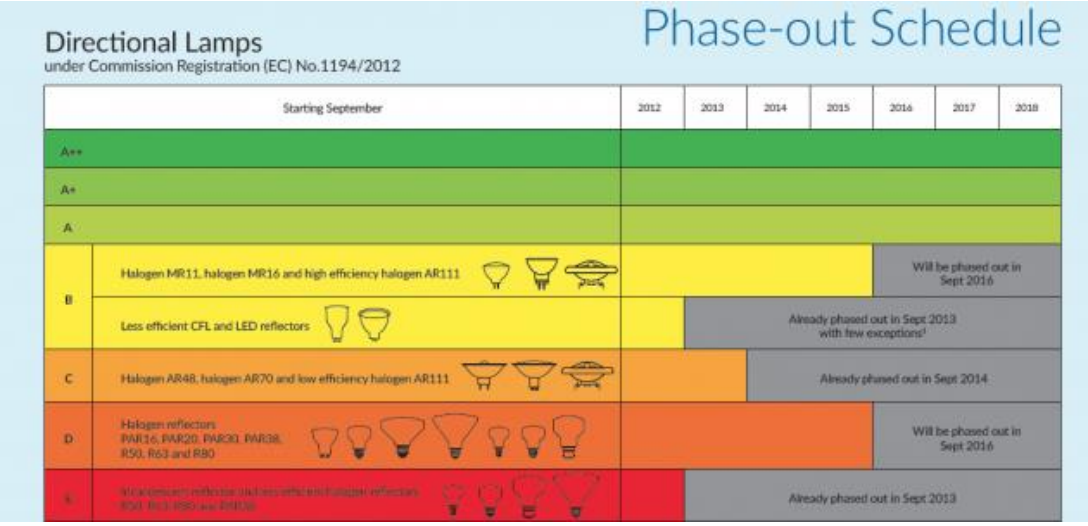

Figure 35: Legal framework for sustainability/energy efficiency: EC phase-out of directional lamps since 2009. (Luxreview, 2016)

One example is the German Corporate Social Responsibility Act. Since 2017 large companies must not only financially account but also account for their social and ecological actions. Other examples are the EU-wide stepwise prohibition of light bulbs since 2009 or the German Renewable Energies Act (EEG) of 2000, which regulates the massive expansion and feed-in priority of renewable energy and the law for the gradual shutdown of nuclear power plants.

5.2.6 Management systems

Knowledge is only the first step towards a more sustainable behaviour. From the perspective of the non-academic world an established instrument for transforming knowledge into a change of behaviour is the implementation of a management system. The basic management system consists of the four steps *plan, do, check, and act* and then start over again. The usage of such a structured approach helps implementing goals, for instance sustainable behaviour, in organizations. It is necessary, to have the management system's high level commitment to the subject. The success increases even more when also an external audit and certification process is implemented. In business and industries quality management as well as environmental management systems are wide spread and in some cases a necessity. Energy management systems are also well known in energy intensive industries for saving monetary resources. The instrument itself can also be implemented in non-business organizations for achieving defined goals. In the following, a best practice example that combines the idea of a management system with sustainable behaviour in the *European Energy Award* will be described. The *European Energy Award* (EEA) establishes interdisciplinary planning and action as well as a process-oriented and long-term energy and climate protection policy in the municipalities. All municipal energy and climate protection activities are systematically identified, analyzed, continuously reviewed, coordinated and implemented according to the goals set.

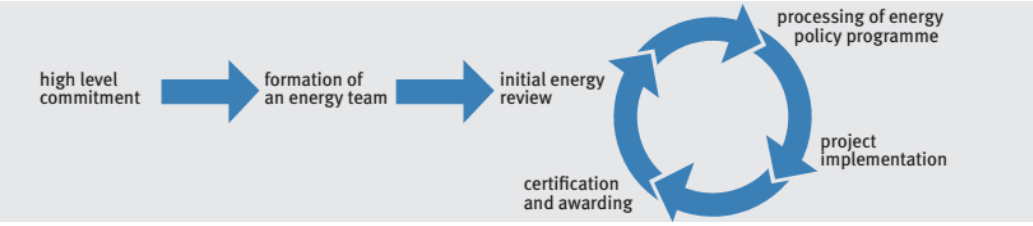

Figure 36: Management cycle of the European Energy Award EEA

External expertise is an incremental part of the EEA where a pan-European network of experts is available for consulting the municipalities, while external certification ensures the quality of the measures. The EEA is not a stand-alone approach but is also interconnected with other programs and activities such as the Smart Cities initiative and the Covenant of Mayors. It corresponds, in the best possible way, to the 20-20-20 objectives of the European Union for 2020.

5.2.7 Networks

Networks provide the possibility to behavioural change for sustainability in a special manner. They offer the possibility publish ideas, questions, concepts, events, best practice and many more. That is especially profitable for companies. They can network together within a region or a branch to face common problems or questions in an efficient way and always at eyelevel. Furthermore participation in an energy efficiency network enables companies to plan economic investments in energy efficiency on a solid data basis and efficiently. The exchange of experiences facilitates implementation and decreases fears. This reduces energy consumption, helps to reduce energy costs and creates competitive advantages. At the same time, companies can position themselves in an important socio-political context and demonstrate commitment to climate protection and technical innovations.

The German ministry of economics, together with industrial authorities, associations and organisations, for example, developed the "Energy Efficiency Networks Initiative". The alliance aims to set up approx. 500 new networks by 2020, thereby making an important contribution towards boosting energy efficiency in industry, the crafts, trade and commerce. An energy-efficiency network consists of 8 to 15 companies. In an analysis of the potential, undertaken at the outset of the network activities, an experienced energy consultant helps companies to pinpoint ways to boost energy efficiency. On the basis of this analysis, each company sets itself a conservation target, and backs this up with action. The overall network also sets itself an efficiency target for the duration of the network activities. During the network process, a regular moderated dialogue takes place in which the participating company representatives exchange experience and ideas.

Further Selected examples

Name	Topic	Country	Link
Heat Networks	Sustainable heating by Sweden	Sweden	*http://heatnetworks.se/*
ISCN	International Sustainable Campus Network	Worldwide	*https://www.international-sustainable-campus-network.org/*
Alliance of Associations Polish Green Network	National alliance of 10 strongest environmental and sustainable development associations and foundations based in the largest cities of Poland	Poland	*http://zielonasiec.pl/en/*
Green Network for Businesses	Helping people save energy every day.	U.K.	*http://www.energysavingtrust.org.uk/scotland/tools-calculators/green-network-businesses*

6 CONCLUSIONS AND RECOMMENDATIONS

Based on the analysis presented in the previous chapters, this section presents a synthesis of main lessons and recommendations for the design of the incentive model and the choice of specific incentive elements and mechanisms for the enCOMPASS end-user applications.

The review of motivational theories, persuasive system design theory, and gamification models has demonstrated that users differ in terms of the motivational affordances they are sensitive to, and the overarching goals they want to achieve, such as normative, hedonic, and gain goals (Lindenberg & Steg, 2007). Such differences between users impose challenges on the design of the incentive model, requiring a model that can engage *different* types of users through a mix of incentive model elements. Accordingly, we here recommend classes of functionalities and identify key aspects that need to be considered as part of the final requirements process and the development of specific solutions in *Task 5.2 Energy consumption visualisation and feedback* and *Task 5.3 Adaptive gamification for behaviour change*.

Raise user awareness by enabling interactive exploration and understanding of energy consumption

Not without reason, self-monitoring is one of the task support design principles in Oinas-Kukkonen's (2013) PSD model. Self-monitoring is applied in many different persuasive systems, both within and outside the environmental domain. Positive effects of self-monitoring have been found on behaviour and its underlying attitudes (e.g. Hamari, 2014). Research in the specific domain of environmental psychology suggests that feedback can influence the underlying beliefs and attitudes towards water saving (e.g. Steg et al., 2014). Feedback is an often-explored strategy for inducing change in energy consumption behaviour. It appeals to the user's need for achievement (need achievement theory, Atkinson, 1960) in the sense that a well-visualized decrease of energy consumption levels feeds the user's feeling of accomplishment, as well as the user's feeling of autonomy (self-determination theory, Deci & Ryan, 2000). In behaviour change applications, visual feedback of the behaviour is usually the main element to incentivize users to save energy. Some examples for visualized behaviour feedback have been presented above, e.g. Gustafsson, (2009); Rist (2014); Froehlich et al. (2009; 2012); Sundramoorthy et al. (2010).

It has been shown that feedback is best combined with other interventions, as information alone is incapable of inducing a sustainable change of behaviour (e.g. Buchanan et al., 2015; Fréjus & Martini, 2016). Consumption feedback should be considered as part of a system of assistance designed to enhance user engagement with energy consumption (Fréjus & Martini, 2016). To be appropriable, it must anticipate user needs evolving over time, it should be functionally rich, containing multiple feedback options, it should be complementary to other forms of assistance, and it should include an estimate of the impact of the energy consumption (ibid.).

Accordingly, consumption feedback in the enCOMPASS user awareness app shall be designed in a way that appeals to different users with different overarching goals, that is easily understandable and that illustrates the possible impact of the consumption. Research has shown that users have different goals with using energy feedback systems (Gölz & Hahnel, 2016) that partly resemble Goal Framing Theory (Lindenberg & Steg, 2007). The goal framing theory thus provides a suitable starting point for the design of the enCOMPASS visualization and incentive model, whereby the different types of goals shall be defined both from literature as well as from the results of the requirements analysis and user workshops. Current results suggest that this should include the goal of learning how to save electricity and possibly other selected goals not directly related to environmental behaviour, but related to important psychological drivers of behaviour e.g. from the Uses and Gratifications theory (see Section 2.2). Particular attention shall also be

paid to the hedonic quality of the application (e.g. “joy of use”), as user acceptance is known to increase when users are stimulated not only by the pragmatic value of an application (i.e. practical usefulness), but also by its hedonic quality (e.g. Hassenzahl, 2004; Venkatesh et al., 2012).

Finally, mechanisms for attention triggering need to be developed, that can make the users pro-actively aware of the application and tips for desired behaviour (energy saving) and thus shall consider user type and context for determining the appropriate content and timing of such notifications. In effect, this is in line with the corresponding early use stories and requirements described in the deliverable D2.1.

Promote commitment by stimulating users to target specific energy consumption goals

Goal-setting has been shown to be an effective technique to induce a change in behaviour (Hamari et al., 2014). This potential can be explained with the Goal Setting Theory, which claims that difficult, specific, context-appropriate, and immediate rather than long-term goals are drivers of high achievements (Ling et al., 2005). Goals are most effective when they are proximate in time, moderately difficult, and specific, with an objective definition that is understandable for the individual (Locke et al., 1981).

In sustainable behaviour applications energy feedback is often combined with goal-setting (e.g. Loock & Staake, 2013, Novak et al., 2016). Loock et al. (2013) have demonstrated that setting default consumption goals affects the choice of a user-defined goal, and that this combined approach of first providing a default goal which a user can then adjust to his/her level of ambition, is effective in reducing energy consumption. A suitable choice of the default goal is crucial for the attainment of the goals, and default goals should be moderately difficult (Locke et al., 1981; Loock et al. 2013). The level of difficulty is thereby also a function of personal context (e.g. size of household) and should relate to historical performance of a given user or user type (e.g. historical baseline) in order to provide a suitable level of reference and perception of attainability by the user. In terms of the PSD model, a ‘reduction’ strategy can be employed in which a larger complex long-term goal is reduced to more easily attainable monthly goals, which is expected to positively influence the cost-benefit ratio of engaging in (in this case) energy saving actions (Oinas-Kukkonen, 2013).

The goals and corresponding behaviour need to be provided in units of measurement that are understandable by the user (Froehlich et al., 2012) and defining the time frame for goal achievement (e.g. monthly goals) needs to consider practicalities of the given setting, user’s everyday context and existing practice. Successful implementation of goal setting shall also include a connection with the consumption visualization (e.g. Novak et al., 2016) and with the attention triggering notifications (see previous sub-section).

In enCOMPASS goal-setting shall thus be included in the incentive model, whereby an effective strategy could be to present the users with a default goal (e.g. on a monthly basis), which they can adjust to more or less ambitious target energy savings. In addition, to reinforce the goal-based incentivisation, achievement of the set goals should also be connected with the other incentive elements, such as virtual, social or physical rewards (see below).

Increase motivation and continuous engagement with gamified virtual, social and physical rewards

As a form of dialogue support (Oinas-Kukkonen, 2013), rewards, credits, points, and achievements are often employed in persuasive systems (for a review, see Hamari, 2014), to increase motivation, and to ultimately enhance persuasiveness of the system. In line with reinforcement theory (Skinner, 1957), rewards can provide reinforcements of the desired behaviour (e.g. saving energy). However, once the reinforcements (e.g. rewards) are removed, so does the desired behaviour (Richter et al., 2015). This suggests that a combination of different types incentives is necessary that ultimately changes the

subjective task values of saving energy. That is, in terms of expectancy-value theory (Atkinson, 1960) energy saving must yield attainment value (doing well on saving energy), utility value (the fit with the task of saving energy with the long-term goals of the user), and/or intrinsic value (enjoyment gained from saving energy). As the motivation to allocate cognitive resources is not only driven by rational thoughts, but also by hedonic values (Steg et al., 2014), appealing to such values by means of playful interaction can motivate users to engage with the application, which can yield value beyond the rewards.

Apart from individual rewards that can ultimately yield subjective task value, social rewards can be used. Different kinds of social support can be employed to increase the persuasive potential of the behavioural change support system (Oinas-Kukkonen, 2013). Social rewards can result from comparing game achievements or energy saving achievements against other users, e.g. by means of a leaderboard that reflects the user's ranking. Leaderboards as competitive elements are often shown in recent behavioural change applications (e.g. Gabrielli et al., 2014), but other approaches such as cooperative social visualizations as virtual social rewards have also been experimented with (Grevet et al., 2010) and present alternatives especially for contexts where competition should not be a key incentive element. Social rewards in general have the benefit of appealing to the basic desires for competition and collection (Reiss, 2002), of providing an opportunity for social comparison (Festinger, 1954) with other users, as 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. Finally, social rewards can provide an additional incentive as they fulfil the need for esteem in the Maslow hierarchy of needs (Maslow, 1943). Successful incentive models thus combine different types of intrinsic and extrinsic motivational drivers, such as virtual, social and physical rewards. Accordingly, the enCOMPASS incentive model will consider such a mixed-model incentive strategy, taking into account the specific requirements of the different types of users and pilot settings (e.g. residential households, schools, public building; see also *D2.1 Early use cases and requirements*).

Strengthen norms with consumption reminders and normative symbols

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. This conclusion is in line with Steg et al. (2016), who argue that symbols that have a normative connotation can be employed to strengthen normative goals. Furthermore, such symbols can convey the injunctive norm, i.e. what ought to be done, which according to Hamari et al. (2014) is a particularly effective strategy to alter people's behaviour. Leveraging this normative influence is also one of the social support principles suggested by Oinas-Kukkonen (2013).

Such reminders shall be included in enCOMPAS as part of the consumption visualizations. Already simple practical symbols can act as both as reminder and convey a normative message include thumbs up (or down), and a green (or red) flashlight, as successfully demonstrated in recent applications (e.g. Novak et al., 2016). Furthermore, to increase their effectiveness, consumption and/or saving reminders shall be connected with attention triggering notifications that can pro-actively raise the user's attention in the appropriate context.

Increase behavioural control with actionable tips

According to the theory of planned behaviour (Ajzen, 1991) and self-efficacy theory (Bandura, 1977), the extent to which a user is confident that s/he can actually perform the desired behaviour affects the user's behavioural intention, and subsequently the behaviour itself. By providing concrete energy saving tips, the user will feel more confident that s/he can actually save energy, which affects the likelihood that the user

will actually attempt to do so. This will support users in ascribing the responsibility for saving energy to themselves, rather than external factors, which according to the Norm-Activation Model (Schwartz, 1977) is a predictor for behavioural change to happen.

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.

As presented in the previous sections in more detail, tips are also one of the most common strategies in recent behaviour change applications. While in many cases, tips are rather general on how to improve behaviour, more recent approaches also aim to introduce contextualized or personalized tips, considering e.g. the type of household of users (e.g., Sundramoorthy et al., 2010).

In enCOMPASS energy saving tips shall thus be exposed to the users with a dedicated page at which the user can browse through the tips *and* through push notifications (attention triggering). The combination with other elements in the incentive model shall ensure that Bandura's conditions are met: gamification and goal setting support motivation, push notifications attract attention, and examples are given through tips and through the leaderboard and other social comparison mechanisms (e.g. a neighbourhood map).

The persuasive potential is increased when the task support and dialogue support design principles of tailoring (adjusting information to the needs and characteristics of the users), and suggestion (offering fitting suggestions for behaviour) are combined (Oinas-Kukkonen, 2013). In enCOMPASS, this will be done by offering context-aware recommendations for energy saving actions, in addition to the aforementioned generic tips.

Continuously trigger user attention through push notifications

As energy consumption behaviour is a typical example of low-involvement, mostly habitual behaviour, in which a pre-existing behaviour and underlying attitudes needs to be altered, and/or energy-efficient behaviour needs to be reinforced, attracting users' attention is of key importance to foster engagement with their energy behaviour and to ultimately change the users' habits. In other words, providing suitable triggers that push the user beyond the behavioural activation threshold (Fogg, 2009) is critical for the success of the enCOMPASS user awareness apps. However, there is a trade-off between unobtrusiveness and scarcity of human attention on the one hand, and the effectiveness of behavioural change incentives on the other.

In enCOMPASS this dilemma shall be resolved by leveraging the potential of adaptivity and push notifications. As discussed in Section 3.3 a substantial share of the research on notifications has been invested in the avoidance of primary task interruptions. Only few studies have been found that investigate personalization of persuasive messages (e.g. Kaptein & Van Halteren, 2013). A rather rudimentary attempt was done by Gabrielli et al. (2014), using a Wizard-of-Oz technique, with which a human facilitator would prompt personalized notifications for more sustainable transport choices, thus only simulating such a system. No research has been found specifically on adaptive notifications that were designed to maximize both unobtrusiveness and persuasion. The timing, the content, and the differences between buildings in the pilots constitute design challenges for enCOMPASS. User context data, user-generated profiling data,

and feedback to recommendations shall be used to determine the most suitable moment of delivering the push notifications, while taking into account the behavioural change needs of different types of users.

Engaging users through a hybrid card-digital game

The context of schools and households is especially sensitive to the use of games with a purpose, which effectively exploit a procedural representation approach, i.e., a form of symbolic expression that uses processes rather than language to convey 'how things work' (Bogost, 2007). In the sustainability domain, games with a purpose support mutual improvement in the adoption of more sustainable life styles and favor the diffusion of good habits, exploiting a collaborative, action-oriented model for social learning also based on a mild competition scheme at the class, neighborhood-based or office level.

As shown in previous projects (Fraternali et al 2015), the most effective impact can be achieved by coupling real games and digital games in original ways, so to reap the benefits of both paradigms. Real (e.g., card or board) games have been played by humans for centuries, have very well-known and successful engagement strategies, and can transfer behaviour change stimuli and awareness inputs effectively without compromising fun and playability. On the other hand, when they are used as a reinforcement of other persuasive tools, e.g., gamified systems based on the collection, analysis, and rewarding of real consumption data and digital activity, the best strategy is to connect the real game and the persuasive application into a holistic approach. A way to implement such a connection is to integrate the real game with an (optional) digital appendix, which can act as a bridge between the use of the real game and the digitally-mediated persuasive application experience. The digital extension of the real game can piggy back on the game mechanics, injecting some extra rule or step, and the outcome of the digital gameplay can become an additional input to the incentive algorithm of the gamification engine, closing the loop between the user's activity in the digital and real world.

Overall, the presented analysis of the incentive models and applications, together with the identified recommendations for the design of the enCOMPASS system and with the findings from *D5.1 Behavioral change models and determinants for energy consumption* provides a sound theoretical basis for informing and complementing the user-centered requirements analysis and specification for the enCOMPASS system performed in WP2. Specifically, the presented analysis is informs other deliverables and tasks as follows:

- Most of the design recommendations and principles identified in this deliverable have already been used as input and integrated into the requirements analysis and specification process (see *D2.1 Use cases and early requirements*).
- The identified design recommendations and principles will be addressed in more detail in the second requirements iteration (producing D2.2 Final requirements, M12)
- The tasks where specific solutions and elements of the enCOMPASS system are being developed (e.g. T 5.2 Energy consumption visualization and feedback, T 5.3 Adaptive gamification for behaviour change, T 5.4 Hybrid digital-physical energy games for behaviour change) will also be influenced by the analysis done in this deliverable.

In addition to such an "internal" value for the enCOMPASS project, this deliverable also presents a valuable resource of its own, that can inform other researchers investigating and designing behavioural change systems in the energy saving domain.

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