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CoSSMunity: Applying Gamification to create Informed Energy Users within a Smart Grid Community.

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Abstract

As the world's population continues to grow, the importance of energy efficiency is getting increasingly dire. The amount of fossil fuels and and kilowatts a household expends has to be reduced. One way to accomplish this is by using green energy in the form of solar panels, and to educate the owners to utilize the energy in a smart way. Such a user will need tools in order to learn how much the house and its appliances are spending, how to save energy, and shift the timing of the expenditure according to availability. This project will introduce an ICT concept, which aims to inform the users of their behaviour, give tips on how they can improve it, and gradually persuade the users to change their behaviour into a more efficient one. The concept has adopted different behaviour change methods and theories, such as *feedback, gamification, and social norm.*

This study follows the design science research methodology and results in a *working prototype* of the behaviour change technology. This prototype is evaluated through an expert evaluation in the form of a semi-structured interview session. The findings of the evaluation suggest that the prototype is a solid foundation in regards to creating a successful persuasive ICT. However, the findings suggests that the user should be able to choose what information is presented. This is in order to keep the information understandable concerning difficult terminology and measurements. The information given should also provide suggestive feedback to the users, so they can utilize the feedback from the system and learn how to be more efficient. The participants of the evaluation presented creative ideas ideas for improvement in regard to these findings. These have been documented and should be considered during further development of the prototype.

Although findings from this study show that the foundation has been made, further research is required in order to determine the level of relevance of the ICT and if it is of a successful persuasive design.

Keywords— Persuasive Design, Persuasive ICT, Motivation Change ICT, Gamification, Behaviour Change ICT, Energy Efficiency.

Preface

This thesis is submitted to the Norwegian University of Science and Technology as part of a master's degree at the department for Computer and Information Science. Dr. Babak Farshchian, senior researcher at Sintef and NTNU, Trondheim, has supervised the work. The work extends an ongoing research project by the European Union called CoSSMic.

We would like to thank our supervisor for the patience,guidance and valuable feedback through the course of this project. We would also like to thank Leendert Wienhofen and Thomas Vilarinho of the CoSSMic project for invaluable assistance and input. Last but not least, we would also like to thank Peter Ahcin and Erica Löfström for their participation as expert evaluators, their input and enthusiasm.

Abbreviations and glossary

Abbreviations

API - Application Programming Interface.

CoSSMic - Collaborating Smart Solar-powered Microgrids.

Emoncms - Energy Monitor Content Management System.

FBM - Fogg Behaviour Model.

GUI - Graphical User Interface.

ICT - Information and Communication Technology.

PV - Short for PhotoVoltaic, this term refers to PhotoVoltaic solar panels.

REST - Representational State Transfer.

TAM - Technology Acceptance Model.

Glossary

Application Programming Interface - An API in computer programming refers to a set of tools, routines and protocols to interact with a computer system. For example application developers can access Facebook data through the Facebook Graph API.

Autonomic computing refers to the self-managing characteristics of distributed computing resources.

CoSSMic Project - An EU funded research project conducted by different research partners located in Norway, Germany, and Italy.

CoSSMunity - Term coined by the authors as a catchy name for the gamification element added to the project. Gamification is explained in detail in section 2.4.

CoSSMic Score - A term closely related to the CoSSMunity, this refers to the point system used in the gamification element.

Design Science Research - Design science is a problem-solving paradigm that seeks to extend the boundaries of human and organizational capabilities by creating new and innovative artefacts.

Graphical User Interface - A visual way of interacting with a computer using items such as windows, icons, and menus. Used by most modern operating systems.

Representational State Transfer - REST is an architectural design and approach to communication between web services.

Technology Acceptance Model - A model used in information systems that models how users come to accept and use a technology.

Usability - Ease-of-use or user-friendliness of the system.

Widget - A dynamic panel, and part of the website. Although Widget most often describe separate applications on websites, we found it to be the closest word and thereby use it as a term for the panels of content on the system pages.

Contents

1. Introduction

1.1 Motivation

Residential electricity consumption accounts for 40% of global energy-related CO_2 emissions and is expected to grow globally to 58% by 2030 [33]. Therefore, it is vital that initiatives are taken to decrease the expenditure in household's worldwide. In order to do so, it is required that residents use energy in a smarter way, and to do this they must change the habits, knowledge and motivation towards reduction in daily consumption of electricity at home. Not only is it desirable to reduce the amount of kilowatt per hour but also reduce the consumption when the load is high on the main grid. One way to accomplish this, is by using green energy in, the form of solar panels and to educate the owners to utilize the energy in a smart way. In order to achieve this the households need tools, which will help the occupants to change their behaviour to a more energy efficient lifestyle. By making the occupants aware of their expenditure and habits, one might persuade them towards the target behaviour. Gamification has become a very popular tool in order to achieve exactly this. One definition of gamification is "the use of game design elements in non-game contexts" [10]. It has been widely used within healthcare, social, and commercial applications, and it has proven to be a powerful factor to increase participation [10] [11][9].

The effectiveness and success of a smart meter installed in a household heavily depends on the participation and acceptance of the user [15]. One of the challenges regarding this has been that the feedback has not been suitable for the user. This became an unmotivating factor, hence the user stopped using the system after a certain period of time. This resulted in a rollback into a similar habit pattern. In order to keep the user engaged in the system, it is vital that the design of the ICT stimulates both the intrinsic and extrinsic motivation [34].

This dissertation investigates how to find a good combination of tried and tested behaviour change theories, and combine this with gamification in order to increase the level of participation of the end-user. The authors have come up with a gamification concept they have chosen to call "CoSSMunity". Throughout the report, the term "users" are defined in terms of those who use the hardware and software associated and developed by CoSSMic and includes owners/users of schools and residential houses.

1.2 Context of Study

This project has been running alongside CoSSMic, which is an EU funded research project (see section 1.2.1). The concept is built upon the product of the CoSSMic project's numerous design workshops that resulted in different artefacts through a user-centred design process. These artefacts were the starting point for this thesis work.

1.2.1 The CoSSMic Project

The CoSSMic project is a European collaboration between institutions located in Germany, Italy, Netherlands, and Norway. The main goal of this project is to enable higher rates for self-consumption of decentralized renewable energy production by coordinating the energy production and consumption in a neighbourhood. The project will create an autonomic ICT system that will work as a peer-to-peer collaboration between micro-grids within a neighbourhood and with the public power grid. The system will optimize the exploitations of the energy sources and sinks in the neighbourhood, by allowing the individual households to set constrains, smoothing out the variation in load towards the grid, ultimately reducing the fossil fuel based backup power and reduce the electricity bill of the households.[6] [40] [22]

The participants of the project have been handpicked on the criteria that the participants should be equipped with: *PV(solar panel) roof system, smart meter, electrical heat pump, one or more refrigerators and/or freezers, air conditioner or passive cooling system (summer), electrical vehicle(s) (bike, car).* This section will give an overview of the participants of the CoSSMic project and the most essential equipment.

Konstanz

The users in Konstanz consist of two industrial users and three private users. Out of the private users, two have a PV system installed, one of which has a storage device in the form of an e-car.

Caserta

The users in Caserta consist of three private users, one swimming pool and eight schools. Out of the different user categories, only one private user and one school does not have PV systems. This private user has an electric car and the household has been installed with a smart metering system prior to CoSSMic project.

1.3 Research Aim

The goal of this project is to design and evaluate a gamification concept along with a new graphical user interface for the CoSSMic project. The gamification concept and GUI will employ behaviour change elements and motivational theory. The gamification concept will henceforth be called "CoSSMunity".

1.3.1 Research Questions

The authors want to find out **how** *CoSSMunity* makes it more motivating to better the habits regarding a reduced energy expenditure, the timing of the expenditure, and the optimization of different systems installed in the households. In respect to this, the authors have three research questions they seek to answer:

- RQ 1: What do the users think about the amount and quality of feedback provided?
- RQ 2: What do the users think about the gamification element?
- RQ 3: What do the users think about being part of a community?

1.4 Research Method

This study follows Hevner's (2007) *Three Cycle View of Design Science Research.* As a foundation for this thesis, a rigor cycle with a systematic literature study was performed. The relevance cycle consisted of analysis of the existing requirement specifications and design artefacts derived from the workshops mentioned in section 1.2. The resulting artefact of this thesis includes a functioning prototype of the CoSSMic system, where the GUI has been redesigned, with a gamification concept called "CoSSMunity". This artefact was a result of the many design cycles carried out throughout the course of the thesis work. The research methodology is explained further in chapter 3.

In order to get a qualitative evaluation of the design artefact, an expert evaluation was conducted in the final relevance cycle in order to assess the result. This was a semi-structured interview session, which included predefined questions for the participants to reflect on and discuss. The participants were also asked to fill out a "Technology Acceptance Model"(TAM)[39][31] questionnaire in order to assess the usability and utility of the new GUI concept and gamification concept. This is explained in chapter 6.

1.5 Report Outline

Chapter 2: Theoretical Background presents the theoretical background and the main findings of the preliminary study which formed the basis for this project.

Chapter 3: Research Methodology presents the methodology used in this study and explains how it was applied throughout the thesis work.

Chapter 4: Design describes the design process, system functionality and explains how the authors have built upon the CoSSMic project design artefacts.

Chapter 5: Implementation describes the technicalities of the system implemented.

Chapter 6: Evaluation explores the findings of an expert evaluation of the concept and system.

Chapter 7: Conclusion concludes the thesis and outlines how the concepts and implementations may be further improved.

2. Theoretical Background

In order to design a new GUI that will trigger the participants of CoSSMic towards the desired effects, behaviour change theories and psychological motivation theories were researched. The resulting theories needs to be applicable to the different challenges of creating persuasive and engaging technologies.

This chapter will provide the necessary background for this research and it will describe the most essential behaviour theories and models that have been used to develop the concept of the project. These are summarized in table 2.2, and the main findings of this literature review are presented in table 2.3. How the literature study was conducted is explained in section 3.1.

2.1 Intrinsic and Extrinsic Motivation

In order to design an effective persuasive system, one needs to have decent knowledge regarding the psychological aspect of motivation and take this into consideration when designing the system. One needs to understand why human beings have different levels of motivation and the orientation of the motivation. The orientation concerns the underlying attitudes and goals that give rise to an action. The most basic difference in motivation is *intrinsic* motivation, which refers to doing something because it is inherently interesting or enjoyable, and *extrinsic* motivation, which refers to doing something because it leads to a separable outcome [34]. This motivation type is ruled by social psychology [19][34].

Ryan and Deci (2000, p. 56) state that *Intrinsic motivation* is when a person is motivated to act for fun or challenge rather than because of external prods, pressures or rewards. Further they state that "The inclinations to take interest in novelty, to actively assimilate, and to creatively apply our skills is not limited to childhood, but is a significant feature of human nature that affects performance, persistence, and well-being across life's epochs". This is a critical element in social, cognitive, and physical development as skills and knowledge only grow with the basis of interest in performing actions[34].

Ryan and Deci (2000, p.61) writes *Extrinsic motivation* is according to founded by a set of four regulators: External regulation, introjection, identification and integration. External regulation means salience of extrinsic rewards. Introjection means to act upon your own ego, meaning that you focus on approval from others. Identification means that a person has identified with the personal importance of a behaviour, thus accepting its regulations as its own. Integrated regulation is when identified regulations have been fully assimilated to the self[34].

2.1.1 Organismic Integration Theory

Though the motivational factors described above are important to increase engagement, it is important to note that these factors alone are not enough to create a sound motivational piece of software. Ryan and Deci introduces "Organismic Integration Theory" in the *Handbook of Self-determination Research*(2004, p.15), which explains how different types of external motivations can be integrated with the underlying activity into someone's own sense of self. This means that allowing users to self-identify with goals that are meaningful are more likely to produce autonomous, internalized behaviours, as the user is able to connect these goals to other values already possessed by the user[35]. This translates to the context of this study by creating a persuasive system which is meaningful to the user. If the external goals correlate with the internal goals, values or sense of interest, the user will feel positive to engage in the non-game activity [35], [29].

2.2 Social Norm

Being a part of a group is something that has been important for mankind since the dawn of the human race. From the beginning people have been dependent on the community they are part of, in one way or the other, and being excluded from the group or community was considered the ultimate shame. If we look to the animal kingdom we see the same characteristics; being an outcast from the pack has dire consequences and quite often ends in certain death. Therefore one can say it is imprinted into all of us that being socially accepted is of great importance. This section will discuss how social psychology can be applied in order to achieve a desired behaviour by using social norms as a motivator.

Social approval means to be the object of admiration among your peers while disapproval results in the opposite, namely embarrassment and shame. Other human beings approval makes us happy, and on the opposite side disapproval makes us unhappy. Circumstantial evidence and introspection suggest that many people like to receive social approval and to avoid being the subject of social disapproval [16]. Social approval may be motivating and valued positively because of the material gain it might produce, however Ferh and Falk (2002) believe that most of us also value social approval positively for its own sake. Ferh and Falk discuss how the three important motives - the desire to reciprocate, the desire to gain social approval and the intrinsic enjoyment of working on interesting tasks- interact with pecuniary incentives and creates reason for a person to act[16].

With regards to Ferh and Falk's (2002) discussion, there are interesting cases which depict that pecuniary incentive alone is not the most effective motivator. According to a meta-review performed by Ehrhardt-Martinez, Donnelly, and Laitner (2010), one study that took place in California where 271 households participated, showed that out of the feedback messages received, the one containing information about the neighbours consumption was most motivating and had the greatest effect on the reduction of energy use. Furthermore, the review reported great energy savings in a case study at Oberlin University, Ohio. This study was conducted as a competition between 18 dormitory buildings at campus over a two weeks duration. The buildings were fitted with an aggregate, real-time feedback system, where the students could check their expenditure and the leader board online. This study resulted in an average saving of 32% across campus, where the winning dormitory managed to save 56%. This points out that it was the competition that was the motivating factor for the great success, in addition to the newly formed social norm which emerged from the study [15]. This is also apparent in Allcott's (2011) evaluation of OPOWER's different programs which focused on sending letters about the residential utility customers, comparing their electricity consumption to their neighbours consumption. The households were measured in respect to the same type of houses within the neighbourhood. The letters consisted of how the household was doing compared to average in addition to a smiley face and energy conservation tips. The neighbourhood comparison showed that providing social norm information induces people to save energy [3] [36] [32].

2.3 Persuasive Design Theory

The success of a persuasive technology is heavily dependent on consumer's participation and acceptance. These systems are created to aid a user to change their behaviour. According to Fogg (2009) in his article *A behaviour model for persuasive design*, in order for an individual to adopt a target behaviour they need to (1) be sufficiently motivated, (2) have the ability to perform the behaviour, and (3) be triggered to perform the behaviour. In this paper Fogg (2009, p.5) proposes the Fogg Behavioural Model (FBM) that helps researchers and designers think more clearly about behaviour. It is important to see how the three factors have to be present in order for a change in behaviour to take place. The three factors mentioned have become focal areas for persuasive technology[19]. In general, persuasive design focuses on increasing motivation, increasing ability (simplicity), and triggering behaviour (See fig. 2.1). There are explained in section 2.3.1, section 2.3.2, and section 2.3.3 where Fogg (2009, p. 4) describes them as follows:

2.3.1 Elements of Motivation

Pleasure / Pain

This motivator is different from the two others, by the fact that it is immediate, or nearly so. People are responding to what is happening in the moment. Fogg believes that pleasure/pain is a primitive response, and it functions adaptively in hunger, sex, and other activities related to self-preservation and propagation of our genes. Both of these are powerful motivators, and designers should look into how they can embody these.

Hope / Fear

This dimension is categorized by anticipation of an outcome. This dimension is at times more powerful than pleasure/pain. For example, in some cases, people will accept the pain of a flu shot in order to overcome the fear of getting the flu. Fogg points out that the FBM does not rank the power of the core motivators. However, the designers and researchers should consider each core motivator and apply it to their work as appropriate.

Social Acceptance / Rejection
This dimension controls much of our social behaviour, from the clothes we wear to the language we use. Being socially accepted is a desire that is hardwired into us. Perhaps the desire to not be socially rejected is even more powerful, thus we act according to social norms and rules.

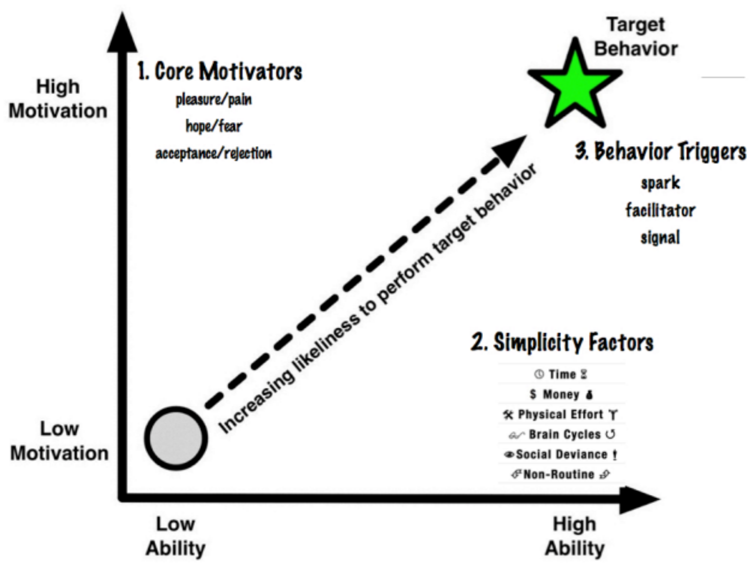

Figure 2.1: All three factors in the Fogg Behaviour Model have subcomponents[19].

2.3.2 Elements of Simplicity(Ability)

Persuasive design relies heavily on simplicity. The reason Amazon.com has been such a success is largely because of the 1-click shopping function[20]. Due to the easy access, people buy more. Fogg presents a framework that includes six elements and an understanding of how these elements are linked together in a chain. If one of the six links breaks, then the chain fails, and thus simplicity is lost.

Time
If the target behaviour requires time, and the user doesn't have time available, then the behaviour is not simple.

Money
For users who do not have a strong financial capability, an expensive target

behaviour is not simple. On the opposite, wealthy people will find this simple. In fact, some people are buying services to make their life easier and to save time. So depending on the resources available, be it time or money, the chain breaks if the resource is scarce.

Physical Effort
Behaviour that requires physical effort may not be simple. Walking from Stanford to Las Vegas is a lot less simple compared to taking a plane.

Brain Cycles
Fogg calls this factor "brain cycles" and it relates to the amount of thinking required to change a target behaviour. If it involves a lot of thinking, it might not be simple. This is an individual factor because some people like to think, and thus this chain link is stronger compared to others.

Social Deviance
Social deviance implies going against a social norm and breaking the rules of society. Hence, if a target behaviour requires a person to be socially deviant, then that behaviour is no longer simple.

Non-Routine
People are creatures of habits and routine. A target behaviour requiring a person to do something not routine is no longer simple.

Key Points about Simplicity
The simplicity profiles of people are individual. Some people have more time, more money, or they like to invest more brain cycles, while others cannot[19]. Fogg says that simplicity is a function of a person's scarcest resource *at the moment a behaviour is triggered*. Fogg also says that persuasive design succeeds faster by focusing on simplicity rather than piling on motivation.

2.3.3 Three types of Triggers

A trigger is something that tells people to perform a behaviour now. This is a vital aspect of designing persuasive technologies. For people who already possess the motivation and ability, a trigger is all that is required. Fogg describes three types of triggers: sparks, facilitators and signals.

Spark as Trigger
A spark is a trigger that motivates behaviour. This is coupled with the three core motivators, so designers are advised to keep these in mind as sparks can leverage any of these motivational elements.

Facilitator as Trigger
This is a trigger which is appropriate for users that have motivation, but lack the abilities to act upon it. A good facilitator tells users that the target behaviour is easy to do, that it will not require a resource which

is not in possession of the user at that moment. For example a system update that takes one click, so that the user will not spend time and brain cycles to do it themselves.

Signal as Trigger

This is a well-timed reminder to perform a target behaviour. Take the traffic light for example; it does not try to motivate, it simply indicates when a behaviour is appropriate.

2.3.4 ICT Systems as Social Actors

In *Persuasive technology: using computers to change what we think and do*, Fogg (2002) proposes that computing products can be used as persuasive social actors. Fogg states that by designing the technology with this is mind, the product can be persuasive by rewarding people with positive feedback, it can model target behaviour, and provide social support to the user. The fact that people respond socially to computer products has significant implications for persuasion. This makes it possible for the computer product to act on a host of persuasion dynamics which Fogg relates to *social influences*[20]. These dynamics influence peer pressure and social comparison as well as group polarization and social facilitation. Fogg proposes that five primary types of social cues cause people to make inferences about social presence in a computing product (p. 91). Namely *physical*, *psychological*, *language*,*social dynamics*, and *social roles* (See table 2.1).

Cue	*Examples*
Physical	Face, eyes, body, movement
Psychological	Preferences, humour, personality, feelings, empathy, ”I'm sorry”
Language	Interactive language use, spoken language, language recognition
Social dynamics	Turn taking, cooperation, praise for good work, answering questions, reciprocity
Social roles	Doctor, teammate, opponent, teacher, pet, guide

Table 2.1: Fogg's (2002, p. 91) Primitive Types of Social Cues.

In his study, Fogg (2002) points out that the impact of physical attractiveness plays a big role with the persuasive power of the technology. It is reasonable to suggest that a more attractive interface or hardware will have a greater persuasive power than an unattractive technology (physical)[20]. Combining this with onscreen icons, colours, and text messages portraying empathy or joy, might make the user subconsciously think that the computing product has a personality, which in turn might give the user a feeling of affiliation, and thus give a persuading effect (psychological)[20]. Designers can use the principle of praise, by utilizing words, images, symbols or sounds, which may increase the persuasion of a technology (language). Social dynamics can be used in the form of positive reinforcement or give the user the need to reciprocate when the computing system has done a favour for them. Computing technology that assumes the role of authority enhances the powers of persuasion[20]. This might be of the form of a doctor, teacher, judge, or a personal trainer.

These social cues need to be implemented with care. If not, it might be of annoyance and the user might stop using the technology. Getting the same motivation dialog every time the user interacts with the systems is repetitive, and this has an adverse effect. Therefore, the designers need to have this in mind and craft the dialogue and praise so that it does not feel repetitive.

A study performed by Consolvo et al. (2008) showed that the effect of using praise through the use of images motivated the participants to either perform physical activity, or use the *planning* function. The study consisted of evaluating a mobile device (UbiFit Garden) that inferred the users level of physical activity and motivated to perform some sort of physical activity. The study had a three week field trial where 12 participants where fitted with the UbiFit Garden device.

Figure 2.2: The UbiFit Garden[5]. a) Start of the week, the butterflies indicate possible goal attainments. Lack of flowers means that no physical activity has been performed. b) a garden with workout variety. c) UbiFit Garden on a mobile device. The large butterfly means that a goal has been reached.

Consolvo et al. reported that the participants said the garden metaphor was motivating, and they wanted to get even more flowers on their background wallpaper. It is apparent that this system has some of the social cues that Fogg mentions. The flowers are an embodiment of praise and positive reinforcement for their efforts. Some of the users mentioned that getting fit or losing weight takes months; however, being able to see these flowers as a symbol of progress and achievements was indeed motivating[5].

Another study conducted by Foster et al. (2010), evaluated the reduction in household energy consumption by the use of social networks. They proposed an application called Wattsup which displays live autonomously logged data from Wattson energy monitors, allowing the user to compare the consumption with other users on Facebook. Wattsup was implemented in eight households, and the trial period was 18 days. The users were split and given two different implementations of the Wattsup application, one with connectivity to Facebook, and one without. The result of the study showed that the reduction in electricity consumption was much higher with the version that was connected to Facebook. Interestingly, the amount of visits to the application was also five times higher when they had the opportunity to compare themselves with their friends on Facebook [21]. The users spent most time on ranking interface viewing and commenting on the ranking. Being that the motivation had roots in the economical incentives which Fehr and Falk (2002) mentions (see section 2.2), it is apparent that this is not the only motivator at work in the social version of the implementation. Social acceptance, extrinsic motivation in the form of competition, and the ranking element are factors that undeniably were present as the participants used Wattsup.

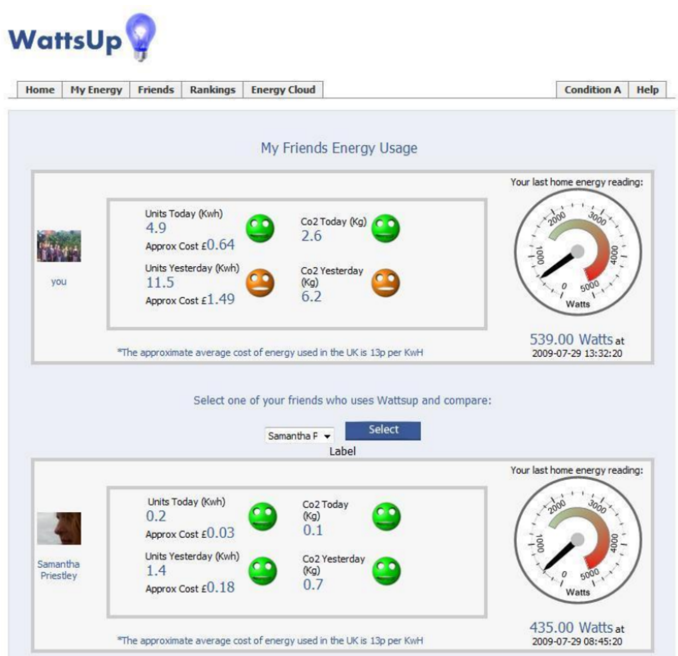

Figure 2.3: "Friends screen" on the WattsUp application [21]. The users can compare themselves with friends and send a friend a message in regards to consumption and savings.

2.4 Gamification

The word ***gamification*** is described by the Merriam-Webster dictionary as: "The process of adding games or gamelike elements to something so as to encourage participation" [27]

Gamification is a concept that uses video game elements to improve user experience and user engagement within a non-game environment or application [11]. This has proven to be a very powerful tool in order to engage users in a more effective manner if implemented properly[11][10]. In persuasive technology, video games and game aspects have been studied as potential means to influence the users actions towards the desired direction intended by the system designer, or to instil embedded values. The reason the gamification concept has been so widely used is because of the way games motivate. Namely because games impact the cognitive, emotional, and social areas of players[11]. Therefore, the gamification elements in the different ICTs should also focus on those three areas of motivation, no matter the sector of the implemented ICT.

In the article *"A User-Centred Theoretical Framework for Meaningful Gamification"*, Nicholson (2012) applies the concept of "situational relevance" onto the gamification concept. Nicholson says that a user has to be involved in the process of determining the rules and goals in a game, so it is in fact relevant to the situation and user. The relevance of the game has to be in accordance with the user's background, interests, or needs. Nicholson calls this "Meaningful Gamification" and he defines it as follows: *Meaningful gamification is the integration of user-centred game design elements into non-game contexts.*(p. 1) The implications of focusing on user-centred design can help the designers avoid meaningless, or worse yet, harmful gamification[29]. Nicholson says using external rewards to control behaviour creates a negative feeling for the user about the non-game context; therefore, the use of external rewards is not user-centred. He proposes instead, user-centred game design elements have to be meaningful to the user and should result in positive change in the user's mind-set. When designing applications with gamification elements, the question that has to be asked should be: "How does this benefit the user?". By taking the user's needs into consideration, the user has a positive and meaningful game-based experience that is well-connected to the underlying non-game setting, and this will benefit the organization in the long run[29].

In their study, Magana and Munoz-Organero (2015) had 36 different participants using a gamification tool designed to help with fuel efficiency. The participant's cars were fitted with an eco-driving assistant that gave the driver a score based on parameters such as: driver must not drive at high speed, avoid braking or accelerating sharply, avoid braking or accelerating unnecessarily, the user should drive at steady speed, and the engine speed should be low. The system also had a relative leader board, which matched the driver to other drivers with the same characteristics. In addition to this, the system awarded the drivers with badges, which indicated what goals the driver had managed to achieve. This study concluded that the eco-driving tool had a positive impact on the fuel efficiency, but more importantly, the study stated that by using the tool, the users managed to stay motivated to become more efficient over a longer period of time. Meaning that they still complied by the rules of the score system given by the eco-driving tool [26].

Denny (2013) conducted a study at the University of Auckland, New Zealand. Over 1000 students participated in the experiment that took place over a four week period. The students used the e-learning platform PeerWise, but with an added motivational element that gave them badges as a part of an achievement system. The study found that the badges had a significantly positive effect on the number of questions answered and the number of distinct days the student were active with the tool. It did not have a reduction in the accuracy of the answers, something that identifies that the answers were genuine and of good academic quality. The students enjoyed being awarded with badges and the students preferred to see the badges in the interface as they were using the e-learning tool. The users were anonymous, so the peers could not see the names of the student with the most badges. Which in turn is interesting in the sense that this gamification element did not trigger or focus on the social motivational aspect, but it did, however, result in a personal affirmation rather than status amongst the peers[9].

Both of these cases are contrasting examples of what Nicholson (2012) stated in his article. However, ”Meaningful gamification” has some good guidelines which is worth exploring. Namely taking the background, needs and expectations of the user into consideration when designing the gamification element (as mentioned in section 2.1.1). This should go without saying, however it seems like a majority of games and gamified applications may be developed on ”hunches” by the designers and developers. By using user-centred design, one can tailor the artefact to fit the users, thus improving the engagement and the fun factor of the gamification element[29].

2.5 Feedback

> The word ***feedback*** is described by the Merriam-Webster dictionary as: ”Helpful information or criticism that is given to someone to say what can be done to improve a performance, product, etc.” [28]

When it comes to learning and altering one’s behavioural patterns, feedback is one of the fundamental aspects. Feedback can be defined in many ways, but Clynes and Raftery (2008, p. 405) described it as: ”an interactive process which aims to provide learners with insight into their performance”. In general, feedback is divided into two main groups: negative or positive. The information given in feedback should include opinion about the performance as well as provide options for improvement [7].

There are many types of feedback with regards to energy, two of the most common being direct and indirect. Of the two, direct feedback yields a higher saving on a general basis with 5-15% reduction reported while indirect feedback results have been measured between 0-10% [8].

Direct feedback consists of types of feedback you get immediately, whether from users monitoring the electricity meter, displays that reveal current energy usage or software giving interactive feedback via computer.

Indirect feedback consists mostly of the energy bill the consumers get from the provider, but can also be expanded to cover for example information brochures etc. that provide general feedback with information on how users can conserve energy.

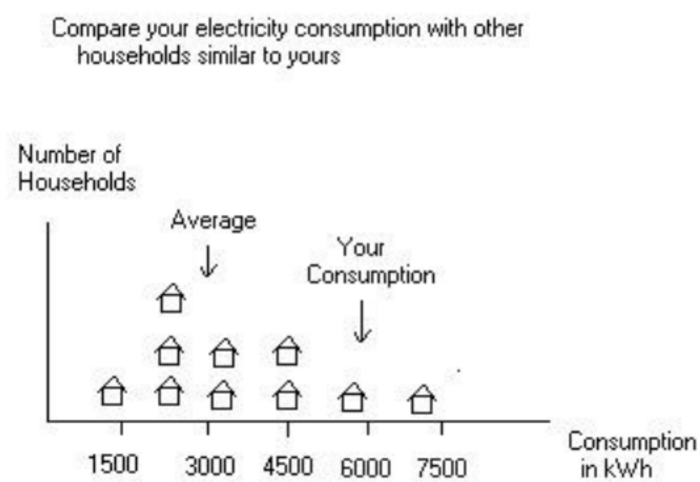

Figure 2.4: An attempt of indirect feedback from the Wilhite (1999) study, where the household is compared to the energy consumption of similar households. Users did not like this design, and it was later changed to match the input from the users

In a review of multiple research projects on feedback with regards to energy consumption by Fischer (2008), several core elements of feedback were identified[17]. These elements were likely to increase the chance of successful feedback, effective both in stimulating conservation and satisfying households. They are as follows:

- Based on actual consumption
- Given frequently (ideally, daily or more)
- Involve interaction and choice for households

- Involve appliance-specific breakdown
- Are given over a longer period
- May involve historical or normative comparisons
- Are presented in an understandable and appealing way

Darby found in a study in 2006 that the lack of useful feedback on household energy usage was one of the prime causes of wastage. In order for users to learn effectively how their consumption behaviour affect energy usage, feedback is a necessity [8].

A study by Dobson and Griffin (1992) in which a small amount of homes were equipped with a device showing electricity usage costs on an hourly, daily, monthly and annual basis, concluded with a 13% energy saving compared to the control group. Even though the sample size was fairly small, the results are significant. A few participants even started researching heat pumps in order to achieve even higher savings, indicating that a deeper motivation had been triggered[12].

A case study conducted Winett, Neale and, Grier (1979), showed that by providing the households with real-time feedback of their consumption, they managed to reduce the consumption by between 10-15% [42]. Although old, this article is very relevant with regards to illustrate the power of feedback. The study took place in a suburban Maryland townhouse community near Washington, DC from January to May 1979. Fourty five participants were randomly assigned to a feedback, self-monitoring, or comparison group. In the feedback group, the participants received a feedback sheet on the door for 28 consecutive days. Each sheet was colour coded, and had an ascending series of smiles or frowns according to the prior days expenditure based on the base line consumption. The self-monitoring group got extensive training and practice with reading the dials of the house electricity meter. They got a sheet at the door every day, which contained the expected expenditure based on the base line consumption. During the intervention and the follow-up period the feedback group and the self-monitoring group had managed to reduce their electricity by 13% and 7% respectively compared to the comparison groups[42].

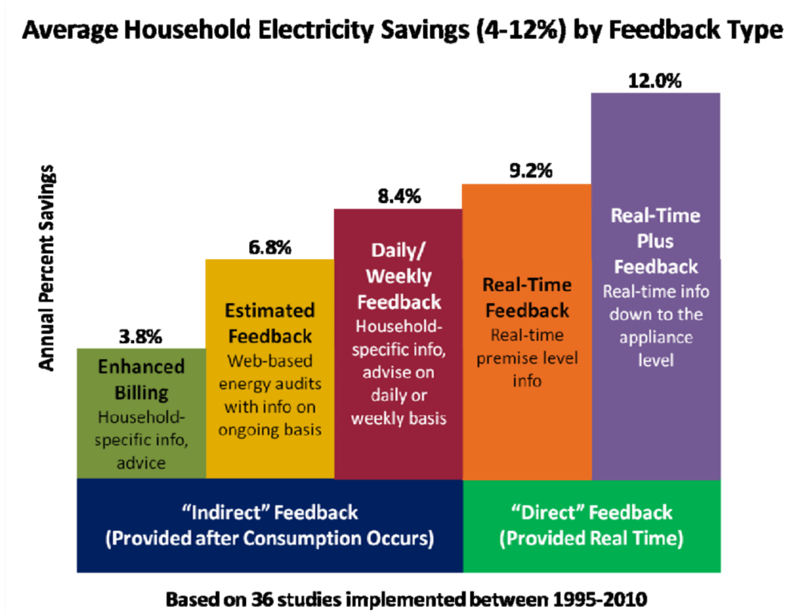

Figure 2.5: A bar chart representing the findings of Ehrhardt-Martinez and Donnely [15]

The feedback provided was of a very simple nature, namely colours and smiley-faces. All though not very technically sophisticated, it certainly managed to motivate the users to use less electricity during both the intervention and the follow-up period. In this particular study the participants were subject to conditioning through positive or negative reinforcement, the feedback created awareness and knowledge towards their expenditure, possibly goal setting, and possibly a challenge between the neighbours [34].

Research done on energy and feedback has so far revolved around conserving energy, naturally enough there is not much data available on effective usage of solar panels on private homes as this is not a common sight in most places. The findings already done on the topic do, however, appear to be valuable with regards to using feedback in order to assist users in efficient use of electricity in homes with solar panels.

2.6 Relevant ICT tools

In order to reach the research goal described in section 1.3, several existing ICTs was reviewed to determine whether one could be used as a basis for this study. This section will describe the strengths and weaknesses of these ICTs, and determine whether they can be used to address the research questions this study aims to answer.

2.6.1 Gamification Similarities

As described in section 2.4, *WattsUp* tries to answer the "one size fits all" paradigm by providing the end-users with feedback, competition through social norms, and comparison. The same can be said about *EnergyWiz* [30] which is designed with the same concepts in mind. These two ICTs are utilizing the *comparison expenditure month by month, social comparison through Facebook, ranking,* and thus competition within the *social norms.* EnergyWiz has however, a more intriguing aspect to it, as it gives end-users the possibility to set goals for themselves and challenge a specific neighbour and EnergyWiz user to an energy saving challenge.

Figure 2.6: *EnergyWiz* main screen and live data screen [30]

These two solutions have many good qualities that make them viable candidates to use within this study. However, there are some intricate requirements that have to be maintained in regards to the users of CoSSMic. Both of these solutions mentioned provide very detailed information about the neighbours, which in CoSSMic's case is not possible due to privacy reasons. The concepts that *EnergyWiz* and *WattsUp* present are worth exploring, however it is necessary to use abstractions when comparing and displaying the users so that their privacy is maintained. Also, the target user group for these two systems is too general. This brings us back to the challenges of providing relevant information to the target users. The CoSSMic users that have a PV system integrated with their house; require information regarding the energy production and/or storage, which none of the aforementioned systems provide. It is also required to use the energy production and storage equipment as parts of the gamification concept. This excludes *EnergyWiz* and *Wattsup* as candidate systems to adopt within this study.

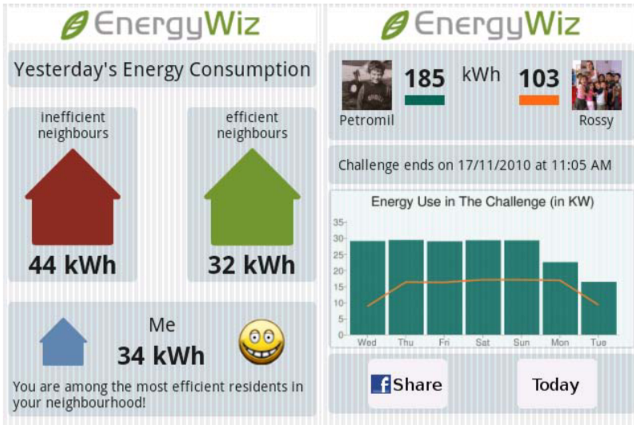

Figure 2.7: *EnergyWiz* neighbours and challenge screen [30]

2.6.2 Automatic Energy Readings and Feedback

Being able to fetch data automatically and provide the user with feedback is a vital part of this study. Not only should the data be automatically collected, but also detail the specific appliance it originates from. In this regard there are many commercialized systems that do this. *Smappee*[38] and *Efergy*[14] are two examples of systems like this. Both of these use smart sockets (see fig. 2.8) which send information about the connected device to the central system. It also provides the opportunity to use a smart phone to see the details of your consumption as well as being able to turn on and off your devices using the smart phones. By using the smart phones, it is easy to provide the end-users with notifications and tips on how to save energy, which gives the users good knowledge about their expenditure. All of this is helpful to change behaviour into a more energy efficient one.

Figure 2.8: *Efergy* socket which goes between the appliance and the wall socket [14]. Same principle is used by *Smappee* [38]

The last ICT which was considered was *Wattitude*[4]. Wattitude provide the users with detailed statistics about the devices over a daily, monthly, or yearly scope. The system allows users to specify whether the devices is producing or consuming energy. The system has a very sophisticated solution to the energy saving tips. The users can make a custom feedback profile by selecting which tips they want or not want to see in the future. This helps the system to tailor the feedback making the system display only the relevant tips for the users.

These systems fall short when it comes to the gamification concept which is planned to be implemented in this study. However, what they lack in gamification, they make up with by using playful design and elegant presentation of the feedback. Also one of the biggest drawbacks the *Wattitude* system, was that the user had to manually input the consumption or production of the devices. Therefore, they serve only as inspirational sources to how one can present information dashboards, feedback, and tips in regards to this study.

2.7 Summary

The theories and methods described in this chapter are of great significance to the research goals of this project. The success of the gamification concept is depending on participation of the users. As described in section 2.4, by defining a meaningful gamification you are more likely to get increased participation. Therefore, the user's participation will be at the mercy of how relevant the feedback, triggers, and social motivators are. This will reflect the coherence between internal goals, values, and attitudes versus the external ones. This will in turn determine how the users react to the GUI concept when it is presented to them.

Theory	*Meaning*
Intrinsic Motivation	To act for fun or challenge rather than because of external products, pressures or rewards.
Extrinsic Motivation	External regulation, introjection, identification and integration. To act on the basis of personal ego, in search of pecuniary incentives or social gains. The synergy between this and intrinsic motivation has to be present in order for an organismic adaption of a motivation or action.
Social Norm	Pecuniary incentives might be an initial motivation factor which marks the start up of a behaviour change phase. However, social norms have proven to be a powerful driving force for a greater participation and a prolonged continuation of a target behaviour.
Persuasive Design	By applying Fogg's elements of motivation (*pleasure/pain, hope/fear, social acceptance/rejection*), elements of simplicity (*time, money, physical effort, brain cycles, social deviance, non-routine*), and the three types of triggers (*spark, facilitator, signal*), one can make a big persuasive influence on the target user. Also by utilizing Fogg's social cues (*physical, psychological, language, social dynamics, social roles*) when designing a persuasive technology, one can improve the persuasive effect in a great way.
Gamification	By using gamification elements one can motivate the user because of the impact on the cognitive, emotional, and social areas of the target user group. Designers can try to use nostalgia in order to trigger emotional motivation, challenging and interesting tasks to stimulate cognition in the user, and using social norms in order to stimulate extrinsic motivation for the users. By utilizing the user-centred design framework, one can increase the level of acceptance and participation of the target users.
Feedback	In order to change behaviour with regards to energy consumption, and thereby also consumption patterns, good feedback is vital. In order to achieve good feedback that motivate the users to achieve this goal it has to be direct, personalized, easy to understand and always available. If this feedback is presented in an appliance-specific manner, given over a longer period of time and in a design that is appealing to users, the chances of successful behavioural change are high.

Table 2.2: Main concepts emerging from the literature review.

Tool	*Phenomenon*
Social comparison	The participants of the *WattsUp* study managed to reduce their consumption by a significant amount when they were using the Facebook version of the application. This was a result of comparing themselves with their respective neighbours [21]. The same phenomenon could be seen in the study at Oberlin University in Ohio, USA. The students living in the dorms could compare their consumption with other dorms on campus using an online leader board. This resulted in reduction of 32% across the participating dorms[15]. These two cases depict the influence of social norms and competition, which proves to be a powerful motivation if used appropriately.
Real-time feedback	As The case study performed by Winett,Neale and, Grier (1979), showed that the participants who got real-time feedback on their consumption, managed to reduce their electricity expenditure with between 10-15% compared to the control group[42]. Ehrhardt-Martinez,Donnely, and Laitner introduces the term real-time plus, which is real-time feedback down to appliance level. In their meta-review, this kind of feedback averaged a 12% electricity saving[15].
Gamification	Though gamification can take many forms, the concept of *Ranking* is considered very interesting. This concept synergizes very well with the social comparison and competition. As shown in the *WattsUp* study, the participants visited the application five times more with the version that connected to Facebook, and they spent most of the time on the ranking page. This indicates that being ranked was a big motivation for the participants, and hence the energy expenditure reduction[21]. The same trend could be seen in the study by Magana and Munoz-Organero, when they fitted eco-driving assistant to the participant's cars. The participants could check their ranking online, and it proved to have a positive impact on the motivation to increase fuel-efficiency and participation in the study[26].
Playful design and metaphors	By using visual metaphors to display performance, participants in the *UbiFit Garden* study were motivated to exercise in order to see the garden grow. The garden was a metaphor for the amount of exercise that had been conducted [5]. The same motivation element was present in evaluation of *Flowie*. This was a tool to motivate elderly people to walk. One of the most motivating elements of this ICT was the animated flower, which was portrayed happy if the participants were active, and unhappy when the participants were inactive [2].

Table 2.3: Main findings from the literature review.

3. Research Methodology

This chapter will describe the use of the *Design Science Research* paradigm in this thesis work. The methodology used is based on Hevner's (2007) *A Three Cycle View of Design Science Research*, which borrows from the framework found in (Hevner et al. 2004).

3.1 Design Science Research

The Design Science Research methodology has been chosen as technique for developing the concept and to try to understand how the concept will influence the users. This research method was chosen because of the way it emphazises clear and consistent definitions, ontologies, boundaries, guidelines, and deliverables for the design and execution of design science research projects[23].

The empirical data from the workshops conducted in advance of this thesis work (discussed in section 4.1) proved important in regards to the design phase of this study. Since there was no opportunity to assess their implementation with the actual users, it was necessary needed to analyze the data derived from the end users in order to maintain the relevance of the system.

The new design was produced through an iterative development process which involved the authors, their supervisor, and two members of the CoSSMic consortium. Six milestones were created and at the end of each milestone, a meeting was conducted to evaluate the new version of the ICT. These meetings served as workshops to refine and improve the concepts which were a result of the legacy requirement specification and design process from earlier workshops conducted by CoSSMic. The main focus was to improve the usability of the system components as some of the components were considered unintuitive. In addition to this, merge the theories and models acquired in the knowledge base with the legacy artefacts.

A new version of the system was presented each meeting, along with new or improved behaviour change concepts. The concept was enhanced through constructive discussions and new milestone goals were set as a result of this. These milestones were reached and presented in the following meeting which in turn were discussed and refined.

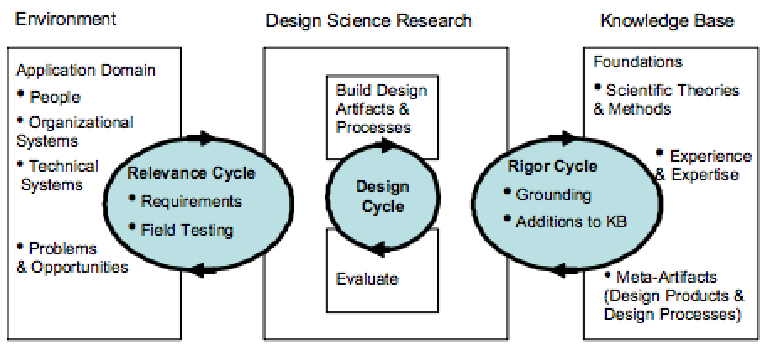

Figure 3.1: Design Science Research Cycles[23]

3.1.1 Relevance Cycle

An application domain consists of the people, organisational systems, and technical systems that interact to work towards a goal [23]. In the context of this study, this means different entities in the CoSSMic project: users, organizers and staff, the legacy requirements specifications and design artefacts, the legacy functional prototype, and the new GUI concept.

By using the empirical data from the design process conducted before this thesis work, analysis of the requirement specifications and design choices of the prototypes were performed. This analysis was in order used to identify opportunities and problems regarding the new version of the artefact. The relevance cycles and field tests could not be performed involving users; however, they were able to demonstrate the newly added features for the CoSSMic representatives attending the milestone meetings.

The final relevance cycle involved an expert evaluation of the new GUI and gamification concept. This is discussed in chapter 6. This semi-structured interview session helped to point out possible problems in regards to future relevance cycles performed with the users of the new system.

3.1.2 Rigor Cycle

This cycle connects the design science activities with the knowledge base of scientific foundations, experience, and expertise that informs the project[23]. The rigor cycle focused on utilizing the experience of other state-of-the-art systems which addressed the issue behaviour change persuasive design. The inspiration derived from the knowledge base heavily influenced the design cycles as the acquired knowledge base was employed to refine the GUI and the gamification concept.

The first iteration of this cycle consisted of a systematic literature study which resulted in 1026 documents, of which 56 were selected and 22 were found to be relevant for the project. The systematic search uncovered two search terms that proved important for the searches that followed and the background knowledge base, namely "Persuasive Design" and "Persuasive Technologies". By investigating the articles returned after searching for the aforementioned terms, essential motivational psychology and behaviour change theories were identified. The collection of relevant literature grew throughout the iterations based on the aforementioned search words and literature provided by the supervisor, and the members of CoSSMic. See appendix A for a full overview of the search words, topics and domains included in the search.

3.1.3 Design Cycle

The nature of this cycle is to generate design alternatives and evaluate the alternatives against requirements until a satisfactory design is achieved [23]. This cycle is tightly connected to the other cycles, and the validity of the two has to be apparant in the resulting design cycle artefacts as illustrated in fig. 3.1. The design cycle is more rapid in regards to building the design artefacts and evaluating them [23] and the evaluation of these cycles was done with the author's supervisor, or one of the two members of the CoSSMic project staff.

The main goals of the milestone meetings were to discuss and evaluate the additions to the artefact. The meetings addressed any discrepancies in regards to the other two cycles mentioned above.

4. Design

Since the choice was to build the behaviour change technology on top of the initial CoSSMic system, it is important that the integrity of the initial design process and its artefacts are maintained. This chapter will describe how these artefacts were created, and the design process for the new version of the GUI and the gamification concept. This chapter will also describe the functionality of the system and how the motivational theories and principles explored in chapter 2 were applied to the design of the new ICT.

4.1 Legacy Design Artefacts

The CoSSMic project conducted three workshops in advance of this thesis work. The goal of these workshops was to create a concept for the CoSSMic ICT, through an iterative user-centred design process [40]. Each workshop produced design artefacts in the form of paper prototypes and requirement specifications for these. In between the workshops, the artefacts were rectified and concentrated by the CoSSMic consortium and presented in the following workshop. After all three workshops had been concluded and the artefacts documented, system designers implemented an initial prototype which was meant to support early user involvement (see fig. 4.4). This was made on the basis of the final paper prototypes (see fig. 4.2,fig. 4.3) and the most important requirement specifications (see table 4.1). These final artefacts are throughout the report referred to as legacy artefact and they were the starting point for this thesis.

In order for the users of CoSSMic to acknowledge the new design of the ICT, it is vital that the requirements specifications are met in order to maintain the integrity of the initial prototype, thus maintaining the integrity of the user-centred design process, the specific needs, and attitudes towards the system from the perspectives of the users. Refer to appendix C for a full list of the requirements specification as well as the different artefacts from the three workshops.

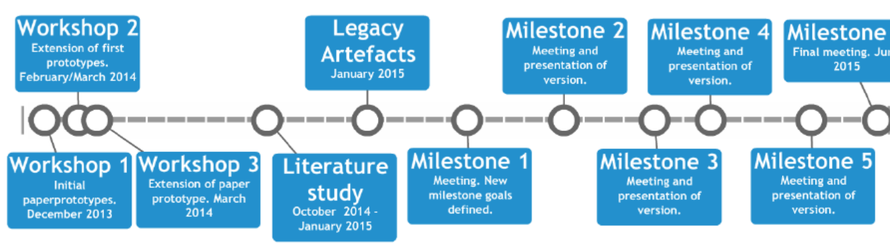

Figure 4.1: Timeline of the iterations of the design phase. The event "Legacy Artefacts" marks the start of cooperation with CoSSMic.

ID	Description	Unit
1	Percentage of **grid** energy used in time_period in comparison to total energy used so far in time_period (where the total is the sum of 1, 2,3 and 4)	percentage
2	Percentage of **cossmic** energy used in time_period in comparison to total energy used so far in time_period	percentage
3	Percentage of **own-pv** energy used in time_period in comparison to total energy used so far in time_period	percentage
4	Percentage of **own-battery** energy used in time_period in comparison to total energy used so far in time_period	percentage
5	Percentage of energy **sold to cossmic** in time_period in comparison to total energy sold so far in time_period	percentage
6	Percentage of energy **sold to grid** in time_period in comparison to total energy sold so far in time_period	percentage
7	Total energy exchanged with cossmic since startup	kWh
8	Current power load during the day	kW
10	Accumulated energy generated by PV during the day so far	kW
13	Weather forecast	-
14	PV performance in the last 12 hours and the performance curve that was predicted for the pv 12 hours ago for the following 24 hours	kWh
15	Scheduled tasks	To be defined
24	Consumption per device	kWh and kW/day

Table 4.1: List of the requirements specification after mock-ups and prototype implementation [40]

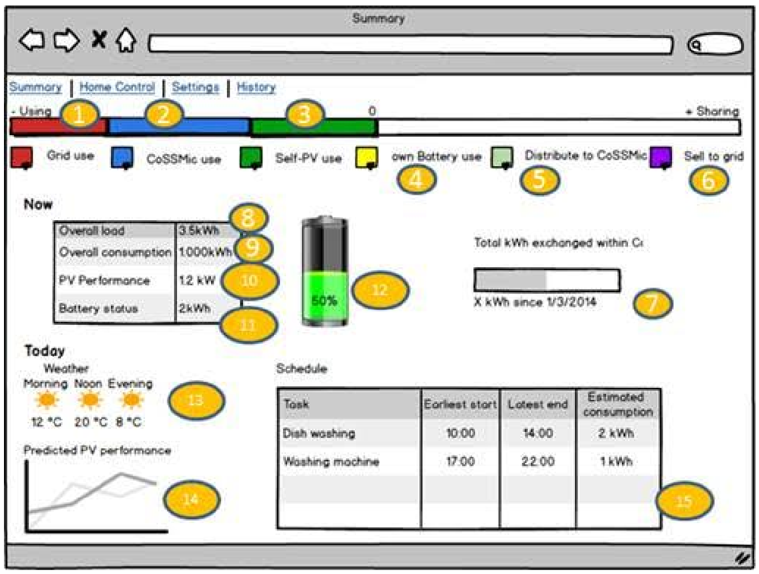

Figure 4.2: Prototype of the dashboard, then called summary screen [40]

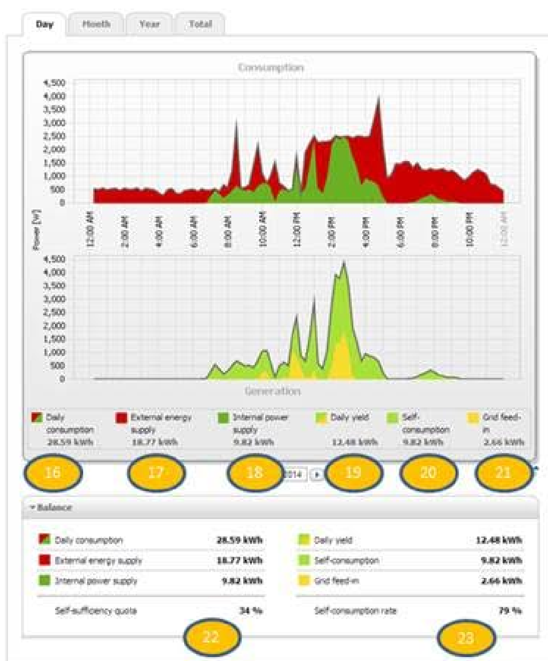

Figure 4.3: Prototype of the history view[40]

Figure 4.4: The first functioning prototype of the CoSSMic technology [40] [22]

4.2 The New System

The findings done in the literature study defined the design decisions in regards to the functionality and features of the new system. The *motivational tools* described in table 2.3 have resulted in the design decisions explained throughout the remaining parts of this chapter. The decisions and the corresponding features are summarised in table 4.2. Furthermore table 4.3 shows how the existing requirements have been met by the redesigned GUI.

The new system is best explained as a combination of an information-station and energy management control and intended to be the sole resource for the entire household when it comes to overview and management of their electricity usage. From a user point of view there will be a total of five pages on the web-application for them to access, all these will be explained in further detail later in this chapter.

Across the world, the notion of being "green" is starting to gain foothold. Early adopters are already starting to supplement their homes with solar panels, and that way purchase less electricity from the grid which might come from high-pollution sources such as coal or gas. Yet many users does not have a grasp on what most of their home appliances cost to use, what in their homes consume the most energy, or the environmental impact of having to scale the power grid to cope with peak consumption. Consumers only know the number they read from the electricity meter and the monthly electricity bill, and with the introduction of smart self-reporting meters this awareness is likely to drop even further. Studies show that in order for the average user to conserve energy, tailored information can make a significant impact in order to empower the user to make the correct decisions [1]. However, when the tailored feedback stops coming, the users fall back into old patterns. This suggests that the personalized feedback has to keep coming in order to maintain the energy savings, which is attempted by displaying icons and information on the basis of the equipment installed in the household such as solar panels and battery.

The new functionality and the result of the research done thus far is the CoSSMunity concept. Although a lot of changes have been done to the way the system presents the information to the user, the CoSSMunity concept is the main addition designed to motivate.

Not only should the feedback be relevant, it should be displayed in an intuitive way. Therefore, great effort has been made to create a system with high usability. To achieve these goals, the user interface has to be modern and pleasing to look at as well as coherent. There should be no room for confusion for any user where to go in order to use the system. Therefore, the design expression has been made as close as possible across all parts of the system, with all content split up into logical blocks contained in simple panels with a title. The idea behind this expression is to allow users to feel familiarity with all pages they visit and keeps the system looking structured and organized which is based on Fogg's key points of simplicity (see section 2.3.2).

The system is designed in a way that the user is given large amounts of feedback while organizing the information so it does not overwhelm the user. In addition, the information has been simplified and been made available through graphics so the threshold for understanding where the energy is coming from and going to is much lower. The colour scheme used throughout the system only consists of a few selected colours, to keep it simple and consistent. The predominant two colours used are plain white and a shade of blue which is the theme colour. The user is presented with only a few pages, so the information is not too fragmented. This is an attempt to embody Fogg's theories of attractiveness and playful design [19]. The different pages will be explained in the following sections.

Tool	*Feature in new prototype*
Social comparison	The forest metaphor used *CoSSMunity Score* is meant to give the users a sense of how they are performing compared to the other members of the community. The user can compare the total score or the different parameters of the bar charts, which indicates the performance in respect to the mean average of the community. A *Ranking* page has also been introduced which will rank all the users within a specific category.
Real-time feedback	The *My Household* widget provides real time feedback in regard to the user's electricity consumption and production. This is also displayed in the *Community today* graph on the dashboard. The *CoSSMunity Score also* provides real time feedback in the form of the bar charts and score parameters. If the user performs an action, the different bars will move and change immediately. The system will provide information and feedback through tooltips which gives the user suggestions on how they can use the system, or improve the scores of the *CossMunity Score* parameters.
Gamification	The *CoSSMunity Score* widget is the gamification concept. It consists of different scores and parameters which are based on actions done in and outside the system. The scores depend on how active the user are when it comes to using the scheduling option, how good they are to reduce the import from the main grid, their utilization of the PV system, and if they are able to share their electricity to the participants of the CoSSMic project. These scores will make up the total score which is visualized in the three. This score is connected to the performance of the community score and the ranking page.
Playful design and metaphors	The tree and forest metaphor in *CoSSMunity Score* is used to create the feeling of a living system which is depending on the actions of the user. They both have moving elements with changing colours which reflects the score of the household and the corresponding community. In order to simplify the concepts derived from the CoSSMic workshops, playful icons have been applied to improve the usability and acceptance of the system as seen in the *Weather* widget and *My Household* widget. All the elements are based on the same colour scheme creating an attractive and consistent interface.

Table 4.2: Summary of the design decisions for the specific behaviour change tool.

ID	Description	Status
1	Percentage of **grid** energy used in time_period in comparison to total energy used so far in time_period (where the total is the sum of 1, 2,3 and 4)	***Satisfied*** in the "My Household" widget in expanded state. The icon and corresponding text is always displayed.
2	Percentage of **cossmic** energy used in time_period in comparison to total energy used so far in time_period	***Satisfied*** in the "My Household" widget. The icon and corresponding text will appear if the system is using CoSSMic Energy
3	Percentage of **own-pv** energy used in time_period in comparison to total energy used so far in time_period	***Satisfied*** is "My Household" widget. The icon and corresponding text is displayed if the household has a PV system connected.
4	Percentage of **own-battery** energy used in time_period in comparison to total energy used so far in time_period	***Satisfied*** is "My Household" widget. The icon and corresponding text is displayed if the household has a battery system installed.
5	Percentage of energy **sold to cossmic** in time_period in comparison to total energy sold so far in time_period	***Satisfied*** is "My Household" widget. The icon and corresponding text is displayed if the household is selling/sharing energy to the CoSSMic members.
6	Percentage of energy **sold to grid** in time_period in comparison to total energy sold so far in time_period	***Not Satisfied*** due to time constraints.
7	Total energy exchanged with cossmic since startup	***Not Satisfied*** due to time constraints.
8	Current power load during the day	***Satisfied*** in the "My Household" widget. Displayed in the house icon as "Total:".
10	Accumulated energy generated by PV during the day so far	***Not Satisfied*** due to time constraints.
13	Weather forecast	***Satisfied***. Displayed in "Weather" widget
14	PV performance in the last 12 hours and the performance curve that was predicted for the pv 12 hours ago for the following 24 hours	***Satisfied*** in the "Community Today" graph. Displayed as "My production".
15	Scheduled tasks	***Satisfied***. A list of the scheduled devices in displayed on the dashboard.
24	Consumption per device	***Satisfied***. Displayed in graph on the "Appliances" page.

Table 4.3: Displaying how the design has met the legacy requirement specifications.

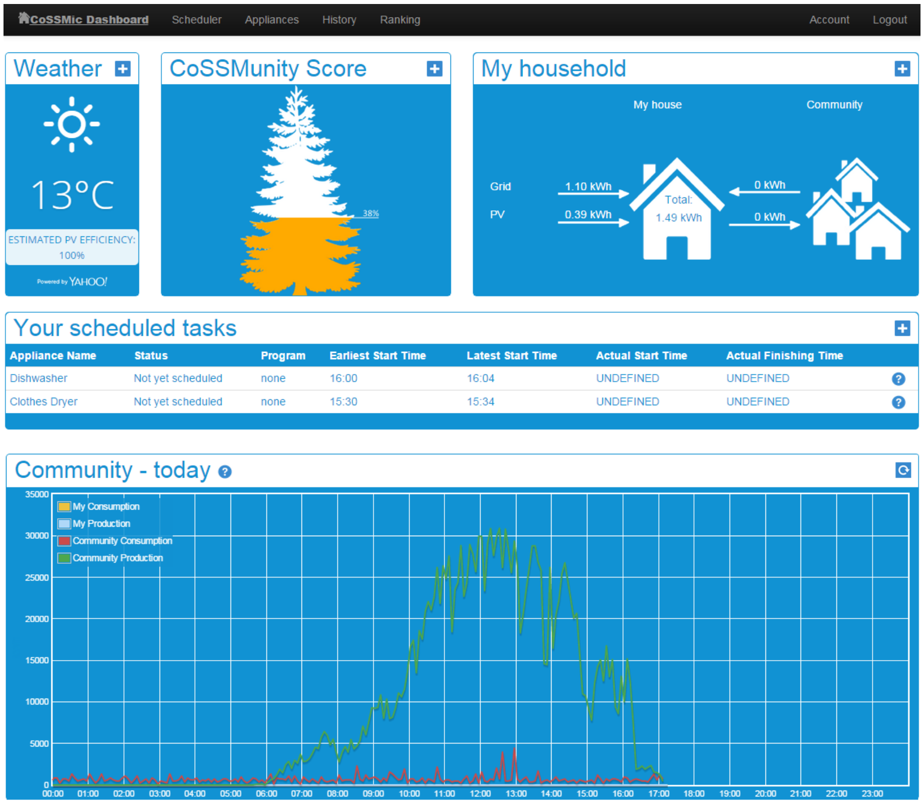

Figure 4.5: The homepage of the new system. The CoSSMic Dashboard allows the users to monitor their energy consumption in an understandable fashion.

4.3 CoSSMic Dashboard

The main page and the landing view, of the system is the CoSSMic Dashboard. This is where the users will get the majority of the information they need on a daily basis. The main components on the CoSSMic Dashboard are explained in the following subsections.

4.3.1 Weather

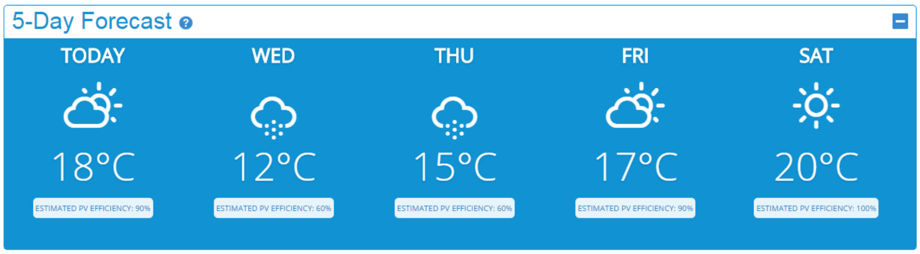

Figure 4.6: 5-day weather forecast on the dashboard helps users plan ahead

The Weather widget is a small panel containing the weather forecast for today (see fig. 4.5). This is a tool for helping its users to plan ahead and make the best out of the electricity produced by their solar panels. Having the weather information available is helpful in order to assist the users to estimate how much electricity is going to be produced today. With a general idea as to how much electricity will be available, scheduling tasks to be run throughout the day is simpler. For additional planning options, the Weather widget can be expanded to immediately show a 5-day weather forecast, if the user desires to plan even further ahead and plan tasks days in advance. When expanding the Weather widget, the CoSSMunity Score and My Household widgets will fade away to leave room for the Weather widget to fill the entire width of the page.

This GUI element is derived from requirement 13 as displayed in table 4.1. This element has been inspired by Fogg's triggers described in section 2.3.3. This is meant to trigger through facilitating[19] the scheduling of the household appliances by displaying the efficiency of the PV system. The scheduling of appliances is an important part of the CoSSMic project, and it is desirable to increase the rate at which the users do this. This is why an estimation of the PV production has been added and enables the users to click the box containing this information to be forwarded to the "Scheduler" page.

4.3.2 CoSSMunity Score

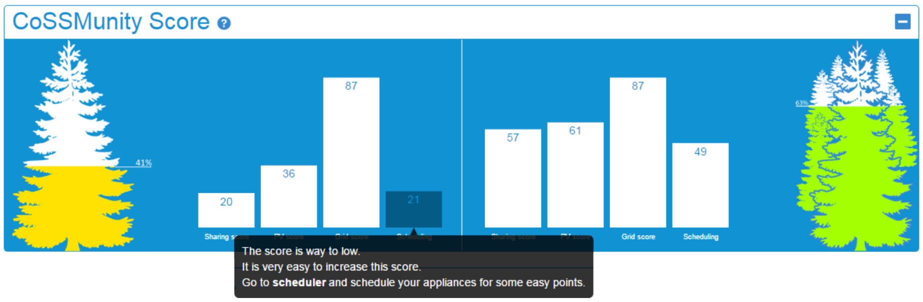

Figure 4.7: Expanded *CoSSMunity Score* box displaying a tooltip based on the score of the "Scheduling" parameter.

The CoSSMunity Score panel embodies the implementation of the CoSSMunity concept. This is the primary addition to the system and designed to be a central component in the users interaction. In its default state it is designed with the intention of simply giving the users the opportunity to assess the household performance. The default state of the panel is as a mid-sized widget panel displaying just a simple colour-coded tree which represents the household performance score (see fig. 4.5). This figure embodies the efforts made by the household to achieve a more efficient electricity consumption pattern, and hopefully motivates the users to continue their efforts by making it easy to set short- and long-term goals. The visual feedback from the tree is colour-coded with colours ranging from deep red to bright green, depicting a poor score or a good score respectively. The score range is from 0 - 100 points. If the household has achieved a score of 55, the bottom 55% of the tree will be coloured in a shade of yellow, while the remainder of the tree is left a neutral white. Lower scores gradually approach the colour of red, higher scores approach the green, while the amount of the tree coloured is equal to the score percentage.

Upon expanding the CoSSMunity Score widget, both the Weather and the My Household widgets fade away and allow the expanded CoSSMunity Score widget to fill the width of the page. In this extended view, users can examine in detail from a bar chart which parameters have been used to calculate the score given. When hovering the mouse pointer over one of the bars, a tooltip will appear to give additional details on why that parameter has a particular score and what the household can do to increase it. The remaining right half is reserved for the community part which is a social concept based on the same principles as the tree. CoSSMic Forest provides the same type of visual gamification element to the CoSSMunity as a whole, using the same calculations and colour-coding, but does this on the values for the entire virtual community. The easy comparison of the household performance with the community performance may become a spark to trigger harder efforts in improving, as elaborated in section 2.3.3, as well as increase desire to obtain social approval and follow social norms emerging within the community[16][19]. The social comparison is in the centre of the gamification concept because of the extrinsic motivation this triggers[34], namely motivation through competition[21].

The tree and forest metaphors used in this widget are designed to motivate the users to get both the tree and forest completely green. This notion is inspired by *UbiFit* garden (see section 2.3.4) which motivated the users to exercise, because they wanted to "grow" their gardens and fill the screen with flowers[5]. The metaphor aims to give the same effect.

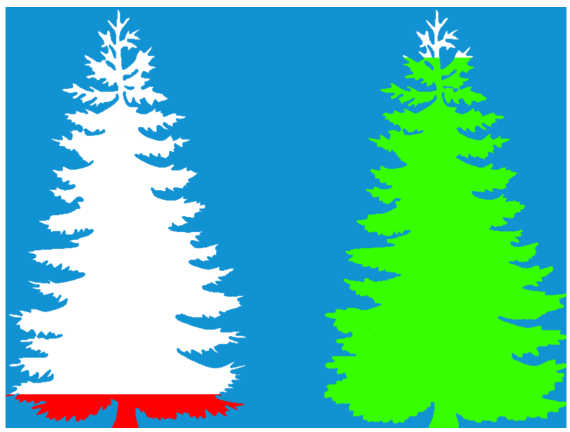

Figure 4.8: Illustration of some of the possible ranges of the CoSSMic Tree. On the left is the tree presented with a 9% score, on the right with an 89% score.

The score system

The idea behind this score system is to utilize all of the resources connected to the household. If the household has connected a PV, a storage unit for example in the form of an electric car, these units should be included in the gamification element in order to maximize the persuasive effect. This is believed to make the gamification meaningful for the users which is important to align the intrinsic and extrinsic motivation values[29][35] (see section 2.1.1).

The scores of the example household (see fig. 4.7) are calculated on the basis of four parameters. This household has just a PV system connected so the system will automatically interpret the equipment connected and present the relevant score parameters for this household. The parameters are:

Sharing score is meant to display how much the users has shared to the other users of CoSSMic. This score is calculated by the fraction of the kW shared divided by a set baseline which is appropriate for that household.

PV score is calculated on how efficient the household is to utilize the PV power which is produced. This score can be high if the PV is supplying the majority of the household's power demand. In order to get the maximum score, the users have to utilize the PV power and schedule devices and run them when the PV is producing electricity.

Grid score is calculated by taking the total percentage of electricity used in the household minus percentage of grid power. If this score is 20%, then the household's remaining 80% power consumption is met by purchasing from the grid.

Scheduling score is calculated on how many times the household scheduled per day or week. If the household has ten appliances which can be scheduled to run, these should be scheduled more than five times per day.

The score system for the CoSSMunity forest is calculated by the average score of the members of the community. In order to maintain the privacy of the users, the community score will display the mean average score of the community members. In the example presented in fig. 4.7, the household is below the average score, which hopefully will trigger motivation to increase the score by competitiveness and fitting in to the social norms.

The bar charts

The bar charts is designed to give the users an indication of how well they are performing within each score category. The bars contain a number which is the actual score parameter. Just as the total score, the score of the individual parameters range from 0 to 100. The bar charts are updated live and as data is updated in the system, the number changes accordingly and the bar chart transitions smoothly into the appropriate height. The number of bars is automatically increased or decreased according to what equipment is present in the household.

The tooltips

By holding the mouse pointer over the bars a tooltip specific for that score will be displayed. These tooltips contain directions and tips for how one can improve that score and a text with positive reinforcement. The tips is designed to trigger by facilitating the users to perform the given action[19] (see section 2.3.3). The message element is inspired by Fogg's theory about giving the system some sort of personality such that the users can think of it as a social actor[20] (see section 2.3.3). This will hopefully increase the influence the system has on the users.

As an attempt to create a better user experience, the "CoSSMunity Score" provides a help tool to give a better understanding of the concept. This tool is enabled by hovering over the question mark icon in the widget header. It describes the motivation behind the gamification concept and practical information about what the different score parameters are and how they can be influenced.

4.3.3 My Household

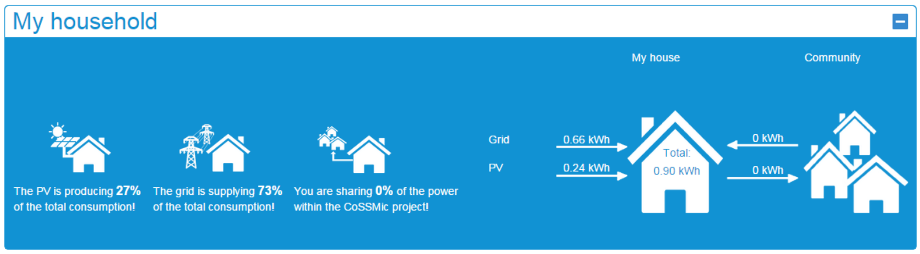

Figure 4.9: Graphical representation of the electricity flow in the household.

The My Household widget in its default state is displaying what goes in and out of the household in terms of electricity. It also displays how much electricity the household is sharing or receiving from other members of CoSSMic. The same transition has been applied when expanding the widget box, making "Weather" and "CoSSMunity Score" disappear and the widget occupy the full width of the screen.

The extended version of the widget displays icons which represent what equipment is relevant to the household's production and consumption. If the household has a battery and a PV, icons will display the current status of the equipment. This means that the feedback is automatically made relevant for the user, instead of ending up with a generic "one fits all" approach. In fig. 4.9 one can see that this house is only equipped with a PV as illustrated by the icon on the left side, and the arrow pointing into the "My house" icon. Everything in this widget is updated in real time and the aim was to simplify the amount of information provided by using a playful design and icons.

The feedback of this widget is considered to be very important in regards to increasing the knowledge within the household. As described in section 2.5, using real time feedback of the consumption within a household can reduce the total expenditure. This is the motivation behind the content in this widget and it is closely connected to the feedback of the tooltips in the "CoSSMunity Score" widget. For instance some of the scores are based on the consumption within the household, and in order to increase the score, the user has to familiarize with the expenditure at that particular moment and act accordingly.

The result of this GUI element is a translation from the prototype displayed in fig. 4.2 and maintains the requirements 1 to 6 and 8 to 11 in table 4.1.

4.3.4 My Scheduled Tasks

My Scheduled Tasks is a full-width panel contains the list of the tasks already scheduled to be run in the household. The list will give the users a simple yet informative overview of what type of appliances will be run in order to assist the users in the decision-making process of planning the electricity usage for the day. The users can interact with any of the scheduled tasks by hovering over the question mark icon. A tooltip will appear containing information about the consumption of the device and how to optimize the use of this appliance by scheduling on a different day or using a more energy efficient program. This list of scheduled devices is based on requirement 15 in table 4.1.

4.3.5 Community Today

A full-width panel contains a graph with a visual representation of vital electricity consumption and production values for both the household and the community the household is a member of. The graph provides an easy to understand visualisation of seeing the peak hours of electricity production by the household solar panels as well as peak hours of electricity consumption. The idea behind this graph is to show users when it is most beneficial to schedule tasks since it is easy to see the difference between PV production and electricity usage. This graph was already implemented in the first prototype of the system and has just been changed to match the colour scheme and the data displaying the users households' consumption and production as well as a zooming function. This graph was derived from the different requirements presented in appendix C, and it was designed and developed by the CoSSMic consortium.

4.4 Scheduler

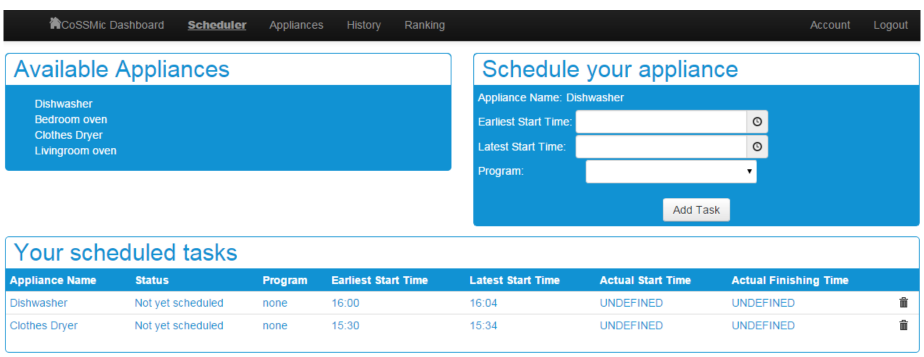

Figure 4.10: Users can schedule their connected appliances to run at specific times through the ICT

The scheduler page is a simple, yet extremely important page in the CoSSMic ICT system. This is where the users can select any of the household appliances available for scheduling and plan ahead, letting the computer system start for instance the washing machine at a pre-set time during the day. In order to connect this page to the relevant elements on the dashboard, the "Weather" and "Your Scheduled tasks" widgets can redirect the users to this page.

4.4.1 Available appliances

The Appliances panel contains a list of all the devices in the household that can be set up to run by the CoSSMic ICT system. Each appliance can be clicked on, revealing the Configuration panel where the users can select earliest start time and latest start time, as well as the program to run and add the task to the scheduler.

4.4.2 Scheduled Tasks

At first glance this list appears to be identical to the list found on the CoSSMic Dashboard. The only differences is that the users can delete scheduled tasks and that this list does not provide tooltip feedback on scheduled tasks.

4.5 Appliances

The Appliances page contains a list of all the appliances which are fitted with a smart meter. It also contains a graph in which the users can see details about what time the device was run and how much electricity it consumed during this time. The different devices can be toggled by clicking on the devices checkbox at the right side of the graph. This can increase knowledge of power consumption, thus enabling users to make more informed choices with regards to their consumption behaviour.

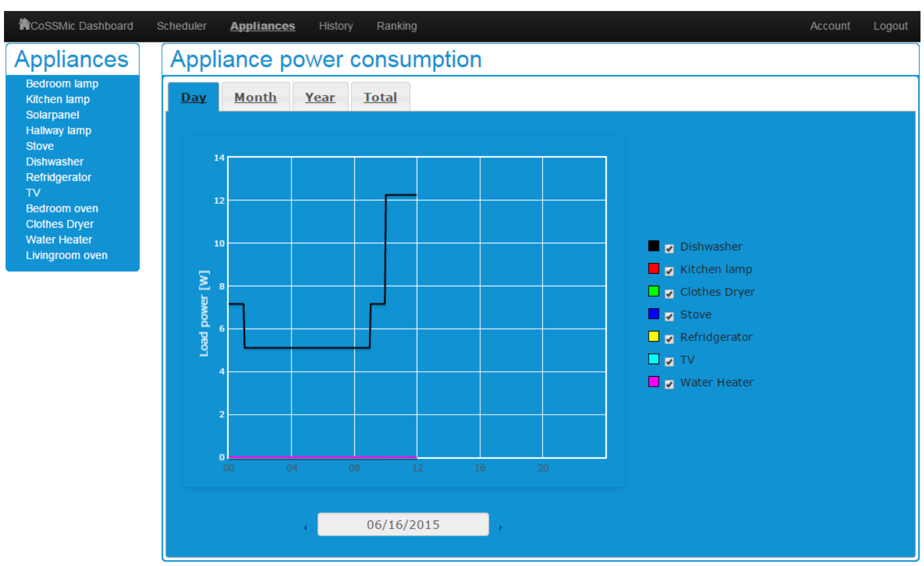

Figure 4.11: The list of all the appliances in the household and the graph.

4.6 History

The History page contains a graph displaying the consumption and production in the household. The users get daily, monthly or yearly history data from the graph. The different values can be toggled by clicking on the different values in the bottom of the graph. This element was already implemented in the original version of the system but has been changed to match the current colour scheme and design expression.

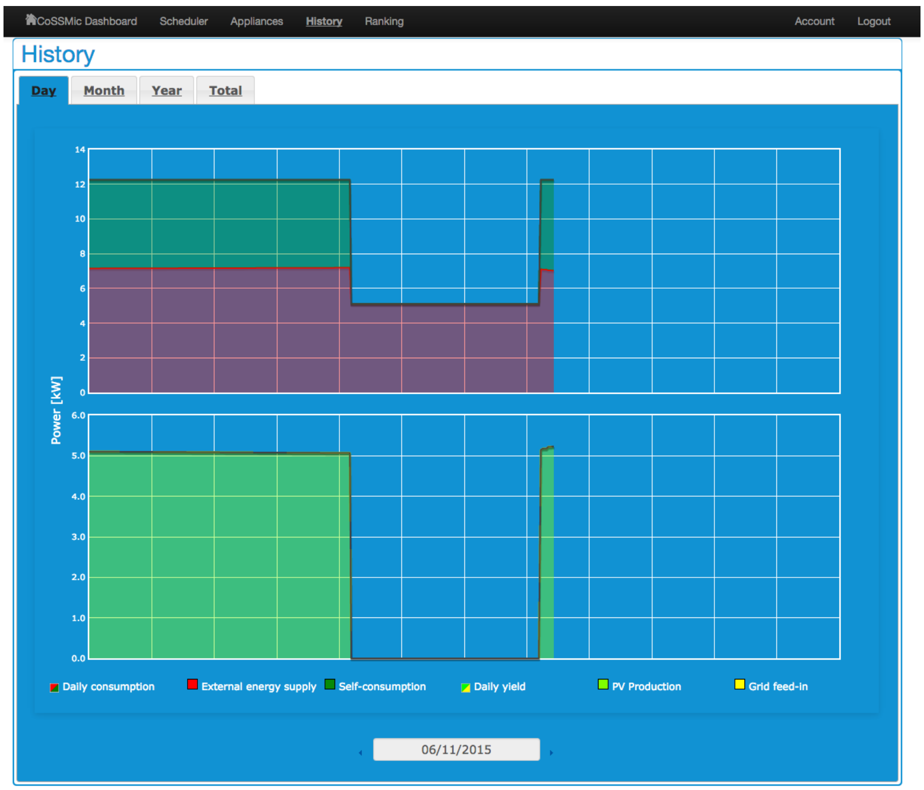

Figure 4.12: Graph displaying the daily history of the household.

4.7 Ranking

The Ranking page contains the rankings of the *CoSSMunity* gamification concept. This page is meant to anchor the gamification and displays the results of the users efforts. As exemplified in section 2.4 and section 2.3.3, using a ranking system showed great participation, and it served as a powerful motivator[21][15]. Thus, the aim for this page is to awaken the competitive nature of the users involved.

The users qualify to compete in the different leagues based on the equipment installed in the household. This is to have the users compete amongst other users within the same category. For example a household without a PV installed will not be able to compete with a household that has a PV installed.

As mentioned earlier, the privacy of the users has to be considered in this context. The users will only know their scores and standings in respect to the other contenders. The scores of the other participants will not be displayed, nor will the names. They will be hidden behind a pseudonym as displayed in fig. 4.13.

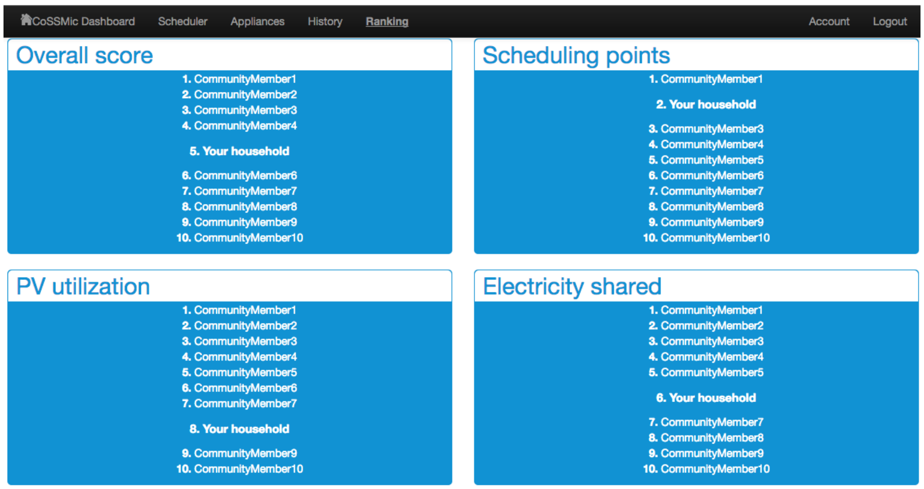

Figure 4.13: The different ranking categories of the *CoSSMunity* gamification concept.

4.8 Summary of the design

The authors have tried to implement the behaviour change and motivation theories to create an immersive and useful system. The result consists of a playful design using icons, positive reinforcement, and specific messages which have been applied on the basis of Fogg's guidelines [19][20]. The aim has been to make the system look like a conscious entity, behaving as a social actor to trigger and motivate the users.

The gamification concept is being displayed in accordance with what is believed will be a meaningful gamification concept[29] for the users. Many of the concepts described in chapter 2) have been adopted many which have proved to be successful as described throughout the literature review. Such as the ranking system and giving score to the sum of actions by the users [21][26][30]. The gamification also adopts the concepts of using social comparison and competition in order to promote higher participation and engagement.

The elements on the CoSSMic Dashboard are all related to the gamification concept. The Weather widget is heavily connected to the scheduling score and the PV score. The information given by the widget prompts the users to plan ahead and utilize the scheduling option. The information given by the My Household widget will make the users aware of their consumption, as well as their production. This will hopefully serve as a trigger to reduce their consumption, and/or shift the time of energy expenditure by scheduling appliances when the PV production is high. The PV score and the grid score will in turn reflect wether the actions done improve the efficiency. The list of scheduled appliances will also influence the knowledge about how much electricity each of the appliances use. Over time the users might learn to schedule the most energy intensive appliances when the PV production is high.

Some changes have been made to the navigation of the system pages. The names have been changed in order to give a clearer meaning to what the pages contain and some elements have been moved in order to get a better consistency and connect the different GUI elements together. However, the requirements set by the users and CoSSMic consortium are still maintained as the system contains the same elements described, though in a new wrapping. This resulted in a simplified and consistent user interface.

5. Implementation

After reviewing the possible candidate ICTs (see section 2.6), it was decided to implement the concept on top of the version built by the system designers of the CoSSMic project. The strength of this system is that it supports the automatic collection of data like *Smappee* and *Efergy*, see section 2.6, and it has a robust REST API allowing for easy fetching, manipulation, and presentation of the data. The weakness of the system is having to design and implement the rest of the desired concepts, corresponding to the behaviour change elements described earlier in table 4.2. This chapter will describe the technicalities of the implementation done in this study.

5.1 Architecture

Based on cross-checking against other open source options and on a testing phase at the trial sites in Konstanz and Caserta, the CoSSMic consortium decided to build the system on the open source software called *Emoncms* [22]. The modified version of this system is designed to run on a server located at each household. The nature of the CoSSMic ICT system is reflected in the fact that it is intended to be used by the household and therefore only has one user per installation. Figure 5.1 shows an overview of the system design as well as the interaction between the user, the system and the CoSSMic Cloud.

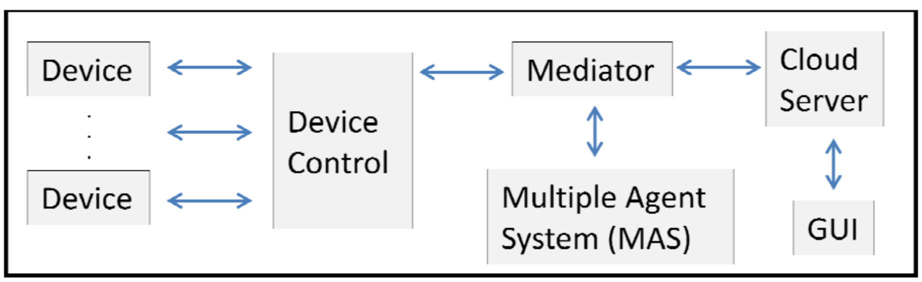

Figure 5.1: The system architecture[22].

The user gains access to the web-application through a browser, while the CoSSMic system itself runs on a lightweight web server physically located in each household. The CoSSMic system silently communicates with the CoSSMic Cloud servers over the internet, uploading the collected data from the local system as well as obtaining the community data through a REST API. User account, appliance information and all collected data is stored locally in a database (see section 5.1.1).

For this project there has not been made any changes to the basic architecture of the system, the focus has remained on the GUI and the way the system functionality is presented to the user.

5.1.1 Database

On each local server there is a MySQL server that handles the storage of all data. The CoSSMic system stores the electricity production and consumption both on a household level as well as on an appliance level in order to have the maximum overview. In addition to electricity usage information, there is information about the various appliances in the household, scheduled tasks that have been set up and of course the user information. During this project, we have done no modifications to the layout of the databases.

5.2 Emoncms

Emoncms, which the project is based on, is written in the PHP language with substantial inclusion of JavaScript functionality. The pages are styled with CSS which gives great control of the design and look of the implementation. All the collected data is stored in a local MySQL database and the electricity usage and production data is also pushed to a centralized server under control of the CoSSMic project.

For the most part the existing Emoncms implementation remains as-is, the specific area where we focus our attention is the GUI created by the CoSSMic project and the addition of the CoSSMunity game element. The dashboard is where the users of the project will go to monitor their performance, check on power usage and pinpoint areas for improvement with regards to their electricity consumption behaviour, and this is where we have made the most significant changes.

Before this project engaged in the redesign of the GUI, the structure of the system was fairly flat and not particularly modern. After the redesign, the interface has a modern look and feel with an appealing graphical profile, which makes use of the motivational theory explained in chapter 2 to capture and engage the user.

5.3 Household implementation

The modified Emoncms system will run at each participating household on a lightweight Debian linux distribution on a RaspberryPi microcomputer. This Debian linux is set up to present users with the Emoncms PHP pages through a LightHttpd webserver. Connected to the RaspberryPi machine is a series of sensors which monitor the electricity situation on selected household appliances for example dishwasher, washing machine, stove and light sources. Storage devices such as battery packs or connected electric vehicle and production devices such as a solar panel are monitored as well. A key point in the entire system is the fact that not only the electricity use is recorded, but also the timeline of the power consumed. An important factor of the decision to have all the households run their own microcomputer controlled system is that internet connectivity is a less vulnerable part of the equation, the data will be collected and the system remains functional even with a temporary loss of connectivity.

5.4 Implementation Summary

Most of the modifications with regards to the system have been done on the user interface. The basic architecture and database schema has not been altered, as that was not necessary to achieve the goal of introducing motivational techniques to the system. Additional functionality has been implemented in the interface, using available data sources and the existing technologies.

6. Evaluation

This chapter presents the evaluation of the new system and how it was conducted. This chapter begins with describing the participants and continues to present the result of the evaluation.

6.1 Participants

In order to evaluate the gamification concept and the new visual changes done to the system, we consulted two qualified researchers in the field and asked them to participate in an expert evaluation. The two participants were:

6.1.1 Erica Löfström

Erica works as SINTEF Building and Infrastructure. Her ongoing projects are linked to the development of sustainable neighbourhoods and housing solutions through the active involvement of end users in the innovation process.

Experience

- Specialized in Science and Technology Studies (STS).
- Postdoc at NTNU, studied carbon neutral lifestyles and challenge of creating the neighbourhoods of the future.
- Interested in exploring how Smart house technology and Welfare technology in combination may contribute to solving the threat of climate changes and that of an ageing population.

6.1.2 Peter Ahcin

Peter works as a research scientist in the field of smart grids and electricity market design at SINTEF and have previous experience with smart home systems.

Experience

- Worked in CoSSMic on the Business Model.
- Worked as business developer at Austrian Institute of Technology, solar energy research group.
- Worked in start-up developing and installing smart home systems.

6.2 Evaluation Method

An expert evaluation session was carried out in accordance with a semi-structured interview which aimed to get qualitative data on acceptance of the system. This addresses the research questions stated in section 1.3.1. The session was recorded on audio to be used for later analysis of the result.

The experts were first presented with a general explanation of what the system is designed to achieve, before moving on to a presentation of the features. The participants were encouraged to discuss as much as possible throughout the session. As a result of this, the participants engaged in numerous discussions regarding the different elements of the system as the presentation progressed.

After the presentation of the system, the participants were asked a series of predefined questions regarding the impression of the GUI and more specific questions regarding the specific elements which involved the gamification concept. At the end of the session, the participants were given a questionnaire following the Technology Acceptance Model standard [39][31]. See table 6.1 and appendix chapter B to see the questionnaire used and the questions asked throughout the evaluation session. The results are given in the next section.

6.3 Result and Discussion

The results are divided into two section: the first will depict the results regarding the overall impression of the GUI and the information provided by the system, while the other will describe a more detailed result of strengths and weaknesses of the gamification concept and the way it is implemented.

6.3.1 Overall Impression and Acceptance

When the participants were asked how they perceived the system, they both indicated they were pleased with how the GUI looked. They both agreed that the Dashboard provided a clear and understandable overview of the system. For example, Peter said: "*It looks very up to date. It looks very clean. I like it in fact.[..] It's very indicative and very attractive and easy to understand.*". Erica agreed to this; however, she said that the household should be represented in the graphs, in order to put the household more in context with the rest of the system. She also advised representing the other households in the same fashion as the *tree* is represented in the *CoSSMunity Score* widget. This was to keep the representation more uniform and consistent.

In regards to the information the system provides, Erica suggested to play more with visualisations and colours instead of only displaying numbers. Erica pointed out that the end users should be able to choose what kind of information they wanted. The participants both commented on the label saying kWh in the My Household figure. They pointed out that the correct annotation would be kW because the information in My Household is "live". They followed up with stating that these annotations themselves proboably do not mean a lot for the general public, and that supports the idea that the information on the Dashboard should be able to change and be personalized according to the end users taste. Erica noted that this would be reflected in a usability test. She also pointed out that the user should be prompted with suggestive feedback on what actions to take in regards to the information provided by all widgets, not only a few. She mentioned specifically that the *Weather Widget* should provide suggestive feedback on what actions to take based on the estimated PV production. While suggestive feedback has successfully been used in the "CoSSMunity Score", the remaining elements in the system were somewhat neglected. This would in turn aid to tie the whole system together as it will become more consistent and connect the different elements.

One of the improvements suggested was to tightly connect the neighbourhood graph with the scheduler system, making it possible for the users to actually drag tasks around on the graph. The effects of this would be that the users could see easily whether the scheduled task coincides with a peak in energy surplus, thus affecting with the user's ability to make the correct decisions. An alternative that had already been discussed during the milestone meetings was to have the scheduling system be displayed as a calendar with colour coded timeslots based on normal power availability. This was presented to the evaluators. Both evaluators really liked the idea to "book" timeslots in a calendar system and suggested a further evolution where users for example could set up how flexible they could be with regards to scheduled tasks to allow the system more control over when they were started. The idea behind the flexibility options is that some users would probably want more control, while others would like the system to handle the details as long as the task gets done.

The participants were asked to fill out a questionnaire at the end of the session. They were asked to imagine a scenario where the CoSSMic system was installed in their apartment building, and reflect on the answers in regards to the knowledge they possess regarding the topic this paper addresses.

The result of the questionnaire suggests some discrepancies regarding the utility of the system. As table 6.1 describes, Erica answers that the utility is good, but it could be improved (six instead of seven). However, she rated the usability of the system to be good. In contrast, Peter answers that the system utility is neither good nor bad (four or five). Nevertheless, he rated the usability to be good. The questionnaire did however indicate that both participants regard *CoSSMunity* as a tool to make it easier to participate in the CoSSMic project, and that it would improve the effectiveness of participation.

		Strongly disagree			Neither		Strongly agree	
	Question	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	CoSSMunity makes it easier for me to participate in the CoSSMic project.						Δ	Γ
2	Using CoSSMunity will improve my environmental impact (performance).				Γ		Δ	
3	Using CoSSMunity would enhance my effectiveness in the CoSSMic project.						Δ	Γ
4	I find the system useful in my everyday life.					Γ		Δ
5	Learning to operate the system would be easy for me.							$\diamond$
6	I would find it easy to get the system to do what I want it to do.							$\diamond$
7	My interaction with the system would be clear and understandable.							$\diamond$
8	I would find the system to be flexible to interact with.				Γ			Δ
9	It would be easy for me to become skilful at using the system.							$\diamond$

Table 6.1: Δrepresents Erica's answers in the questionnaire. Γ represents Peter's answers. $\diamond$ represents answer by both.

6.3.2 Impression and Acceptance of "CoSSMunity"

One of the most vital changes to the system as a whole is the introduction of the CoSSMunity gamification element. As such, it is one of the parts of the system heavily discussed during the evaluation. The ultimate goal with the evaluation is to assess whether the element is good enough to captivate users of the system and motivate them to change towards the target behaviour.

As the presentation of the CoSSMunity Score progressed, the evaluators had many questions regarding the calculations of the score itself, for example with regards to the Grid score and whether it is possible to end up with a negative number on electricity from the grid. It may be technically possible to produce more energy than you need, thus ending up with a negative grid score, but that score would in that case rather be attributed to the sharing score. Erica brings up the challenge that if a user produces a lot of electricity when the grid has too much, it should not be counted towards the sharing score. She admits it is a pretty difficult differentiation to get in such a model, but it is basically no point in saving electricity when the grid capacity is high.

Peter mentions that the CoSSMunity concept looks good as an introduction, as a stepping stone for people to get a graphical and engaging tool to start learning about the consumption patterns and how to be efficient as an energy consumer. However, he believes that once you have actually learned the lessons and the knowledge is present, it will be less useful and the interaction is likely to lessen. Erica interjects that this does not necessarily have to be only a tool for conveying knowledge once, it can also be an activity for example with children to teach them about conservation. If this were to be used to teach children however, some adaptations would have to be made to make it more fun from a child's perspective. The concept of CoSSMunity is embodied by the visualization of the household performance in the form of the coloured tree. Both Peter and Erica agree that this tree as a symbol is efficient and easy to understand, but also that it could benefit from being put more into context with the other elements of the system. As an initial step stone with gamification, Erica comments, this is good. It could be improved with more energy, more moving elements and perhaps even some interaction to make it seem more like a game to the users. Peter on the other hand believes it is slightly unclear what timeframe the CoSSMunity is referring to, which indicates that in order to clarify the meaning of the score the user needs to know when the data is from. Perhaps even make it possible for the user to choose the window themselves, for example see the CoSSMunity score for this week or month.

The participants were asked what they thought about being compared within the community, which Erica thought was a good question to ask during an end-user interview. However, she thinks it is clearly motivating for some people and elaborates: "during a focus group on the possibility to compare, I uncovered that there is a distinct divide on the matter where some are very interested in the comparison, while others are completely opposed to being compared. Very few does not care whether they are being compared or not". Peter said that he never actually liked the idea, though he thinks he would enjoy it if he got the chance. He would try to be a good member if he did not end up at the bottom of the rankings, in which case he probably would lose interest. Erica believes that instead of making this a pure competitive element, that it should focus more on giving positive feedback. The ranking could be an option for those who would like such a competitive comparison, but overall she thinks it would be more fun if the users could see their change.

One of the concerns voiced during the evaluation was that humans tend to grow accustomed to new things. Erica explains: "after a while they get used to it and then it becomes invisible again, so you have further develop your visualisation as you go. You can not have the visualisation once and for all". Peter agrees that changes are likely to be required, "you have the system and it teaches the users, then they have the knowledge. Then over time circumstances change and the user's behaviour has to be corrected then you get new notifications".

6.4 Summary

Table 6.2 summarizes the evaluation session. The *Feature* column is derived from the design decisions which is given in table 4.2 and throughout chapter 4.

Feature	*Evaluation result*
Social comparison	The participants were positive to this concept being used and believed this would motivate some of the users.
Real-time feedback	The participants pointed out that the way the information is presented is in a good and clear manner, though the user should be able to choose the feedback form. The systems should also provide suggestive feedback in all the elements and not just the bar charts on the gamification widget.
Gamification	The participants would like to see more moving elements and be able to interact with the system in a greater sense. They mention that this could be done by adding a drag-and-drop feature for the schedulable devices onto the "Community today" graph. However, they agree that it works well.
Playful design	The system could include more colours and visualizations. This would make the design more playful.
Metaphors	Both of the participants agree that the *tree* and *forest* metaphors are efficient and easy to understand, though they commented that it should be put more in context with the rest of the system. For example the Community Graph.

Table 6.2: Summary of the evaluation session.

7. Conclusion

This report presents theoretical background in regards to persuasive technologies and behaviour change theories. This has been used as a basis to develop a new GUI and a gamification concept for the CoSSMic project. The design is based upon the result of the user-centred design process conducted in advance of this project, where the resulting requirements specifications and initial concept was maintained. This resulted in the gamification concept named "CoSSMunity".

The assessment of this study was done in an expert evaluation with participants considered to be experienced in the research field. The expert evaluation involved a semi-structured interview where the participants discussed in detail how the system was perceived and possible improvements to be considered. The participants also answered a questionnaire following the technology acceptance model[39][31] using a Likert Scale to rate the statements in the questionnaire.

The findings of the expert evaluation session dictate that the information on the dashboard has to be personalized depending on what the individual user wants. Even though the dashboard is clear for the participants, it has to be kept in mind that the understanding of the different terminology varies greatly among end-users. In regards to this, the participants of the CoSSMic project are considered to be of a high level concerning understanding electrical terms and technology. This being said, giving the participants of CoSSMic the choice to change the information to their taste will only strengthen the gamification and playfulness of the design, usability, and functionality of the system.

As Fogg explains (see section 2.3.3), for people that possess the motivation and the ability, a trigger is all that is required in order to perform a target behaviour [19]. From the author's perspective, the participants of CoSSMic falls under this category. Therefore it is very important for the success of this ICT to offer feedback that triggers the users. As the participants of the expert evaluation pointed out, it is important to use suggestive feedback in order to accomplish this. Though parts of the system have incorporated this, it became apparent that all parts of the system would benefit from using real time feedback and a suggestion on how to utilize this or improve upon it [7][5].

The CoSSMunity gamification element has the potential to be a valuable tool to assist in the behaviour change among the CoSSMic users, and as a gamification element it is a good start. Employing a tree metaphor in the gamification intends to appeal to the emotional and social aspects of the users (in this context, conserving environment) and trigger them to desire the achievement of obtaining a full score to get the completely green tree [20] [19]. The expert evaluation concludes that it would be beneficial for the CoSSMunity concept to continue evolving in order to maintain the engagement and enthusiasm of the users.

7.1 Limitations

Due to time constraints, as well as the fact that the CoSSMic users are located in Konstanz and Caserta, it was not possible to get the new improved version of the CoSSMic system field tested by the actual participants of CoSSMic. This limits the conclusion capabilities to only what was discussed during the expert evaluation, and thus it is not conclusive whether the changes and additions to the system actually have the desired effects. Nonetheless, having received good reviews and mostly positive feedback from this evaluation it is reasonable to believe that the project is worth further development. The lack of real user testing somewhat weakens the relevance cycle in the design science research paradigm, though great efforts were made to mitigate the problem by working closely with members of the CoSSMic team. The implementation of data collection methods that would log empirical data concerning the user habits and changes in behaviour, are not in place as of now. This would be beneficial in establishing whether the system is able to motivate its users, and both these limitations are listed in section 7.2, as they are essential in the future work to conclude the concept.

During the expert evaluation, Erica and Peter were given questionnaires to answer after the discussion and could therefore have been influenced by the other participants in the discussion. Thus some bias has been introduced; however, the response from the questionnaire is still considered to be somewhat useful as the project is still in the product development phase.

7.2 Further Work

7.2.1 User Evaluation

As mentioned in the limitations, the authors unfortunately did not have time to get the system ready for a user evaluation. Since the CoSSMic project has decided to adopt and continue the development of the GUI and gamification element created during this thesis, it is encouraged that they eventually perform a user evaluation. Hosting a user evaluation is something that should be done once the system has been refined even further, in order to get fresh perspectives and actual user feedback on the functions and usability of the system as a whole. Since the early phase of CoSSMic employed user-centred design to create the legacy concept, it might be a good approach to continue the development in this fashion.

7.2.2 Empirical Study of the behaviour change

In order to actually verify that the system is having an effect in motivating the users to alter their behaviour it could be useful to implement methods to collect data from the usage. This can be done by recording whether users would go to schedule tasks *after* a suggestive feedback tooltip and compare the efficiency of the household's efficiency before and after the tooltip has been activated. This will require a longitudinal study which will help identify the possible benefits of the gamification element.

7.2.3 Interactive scheduler

Currently the scheduler system allows the users to schedule an appliance to run that same day, and list all the scheduled tasks. This may to some users feel restrictive and unintuitive, and as such the authors propose a major change in the scheduler system. The suggested scheduler system allow users to assign timeslots in a calendar system which for example could be colour coded; green for timeslots with normally high availability of electricity and red for timeslots with low availability. Users would be able to drag an appliance to a specific slot in the calendar to schedule it, expand the timeslot to allow more flexibility in when the system initiates the task or move the scheduled item around in the calendar. Another idea would be to possibly add recurring events, though this may actually be counter-productive as automation may lead to complacency in the users and negative effects concerning efficiency, as such this should be researched beforehand. It is worth mentioning that the engineers working on CoSSMic have been redesigning the way scheduler works, so this may be redundant.

7.2.4 Tasks in neighbourhood graph

In order to more tightly connect various elements of the system, the neighbourhood graph could be bonded with the scheduler system to make the graph more valuable for the users. This could be achieved by displaying small icons for the various scheduled tasks on the graph itself. When a user hovers over the icon, a timeframe for that task could be shown, estimated electricity consumption, selected program and suggested actions.

7.2.5 Graphical improvements

One of the improvement suggestions that came out of the expert evaluation was to increase the level of the gamification. Because neither of the authors come from a graphical design background, the images used in CoSSMunity are now somewhat flat and uninspiring. If the CoSSMunity concept was to be improved by someone to become more lifelike or animated, this would most likely increase the attraction for many users. There is another idea to actually allow the users to customize the look of the entire system, select from colour palettes and different styles of displaying the information. This could for example be done through a set-up wizard that ran once on the first logon and all choices made in this wizard would of course have to be possible to change from a control panel later on. This would allow each user to personalize the system and tailor it to their own tastes and interests which makes it more likely to be used for longer periods.

7.2.6 More suggestive feedback

During the expert evaluation it was suggested to increase the amount of suggestive feedback throughout the system. As it is now, suggestive feedback is used mainly in the CoSSMunity gamification element, but it is possible to extend this functionality to other parts of the system. The weather widget is a prime candidate for more suggestive feedback, seeing as it already has information on the estimated percentage utilization of the PV system.

Appendices

A. List of Literature Review Constraints

We did many searches manually at the beginning to get a starting point with which to base our complete search on. The searches were done in Scopus. The search terms we applied in these manual searches are listed below:
ICT AND Motivation
Computer AND Motivation AND Human
ICT AND Motivating AND People
ICT AND Motivating AND Factor
ICT AND Persuasive Computing
ICT AND Behavioral Change
ICT AND Motivation
ICT AND Motivation Change
ICT AND Persuade AND User
ICT AND Persuasive AND User

Exclusions used in Scopus:

(LIMIT-TO(SUBJAREA,"ENGI") OR
LIMIT-TO(SUBJAREA,"COMP")) AND
(LIMIT-TO(SUBJAREA,"ENGI") OR
LIMIT-TO(SUBJAREA,"COMP") OR
LIMIT-TO(SUBJAREA,"SOCI")) AND
(LIMIT-TO(LANGUAGE,"English")) AND
(LIMIT-TO(EXACTKEYWORD,"Health care") OR
LIMIT-TO(EXACTKEYWORD,"Feedback") OR
LIMIT-TO(EXACTKEYWORD,"Design") OR
LIMIT-TO(EXACTKEYWORD,"Ehealth") OR
LIMIT-TO(EXACTKEYWORD,"Information technology") OR
LIMIT-TO(EXACTKEYWORD,"Technology") OR
LIMIT-TO(EXACTKEYWORD,"Energy efficiency") OR
LIMIT-TO(EXACTKEYWORD,"Computer science") OR
LIMIT-TO(EXACTKEYWORD,"Computer software") OR
LIMIT-TO(EXACTKEYWORD,"Energy utilization")) AND
(LIMIT-TO(DOCTYPE,"cp") OR LIMIT-TO(DOCTYPE,"ar")) AND
(LIMIT-TO(EXACTKEYWORD,"Information technology") OR
LIMIT-TO(EXACTKEYWORD,"Technology")
OR LIMIT-TO(EXACTKEYWORD,"Computer science")) AND
(EXCLUDE(EXACTKEYWORD,"Students"))

Topics	*Domains*	*Setting*
Energy saving	Social network	Youth
Persuasive technology	Mobile data service	Health
Sustainability	Service Type	Students
Household energy conservation	Assistive technologies	Diet
Interventions	Advanced metering	exercise
Health behaviour intervention	feedback	family
Intrinsic incentive	Medical Informatics Applications	Consumers
Participatory Sensing	Mobile	Life style
Motivation	Cooking appliances	Public health
Post adoption behaviour	Mobile phone applications	Weight management
Electricity savings	Phone application	Wellness
Energy efficiency	android	acceptance and commitment
Behaviour change	information and communication	Lifestyle intervention
Behaviour change component	information systems	Mobile health
Self affirmation	IS	education
Electricity bill	eCoach	households
Electricity consumption	Computer system	social context
Residential feedback	Design	-
Energy conservation	Application	-
Feedback	Applications	-
Sustainable electricity consumption	Communication	-
Diabetus Mellitus: Type 2	ICT design	-
Personal health services	ICT designs	-
Behaviour change support systems	Social context	-
Lifestyle intervention	-	-
motivation in education	-	-
Behavioral community psychology	-	-
Energy consumption	-	-
Self-monitoring	-	-
Affordance	-	-

Table A.1: Table displaying the topics, domains, and setting key words used in the search. Each column is joined together with a conjunction. The search was conducted like (”Energy saving” OR ”Persuasive technology” ... OR ”Affordance”) AND (”Social Networks” OR ”Mobile data service” ... OR ”Social context”) AND (”Youth” OR ”Health” .. OR ”Social context”)

B. Questions used in the expert evaluation

Questions Regarding ”CoSSMic Dashboard”
1.1) What is your first impressions of the system?
1.2) What is your thoughts about the information on the dashboard?
1.3) Is there something on the dashboard you fond confusing? If so, what and why?
Questions Regarding ”CoSSMunity Score”
2.1) What is your thoughts about the gamification concept?
2.2) Is there something with this view you find confusing? If so, what and why?
2.3) What is your thoughts about being part of a community?
2.4) What is your thoughts about representing the performance of the household like this?
2.5) Can you think of a way this view can be improved?
2.6) What is your thoughts about giving feedback in the form of tooltips?
2.7) What is your thoughts about sharing to the community vs. sharing to the grid?
Questions Regarding ”My Household”
3.1) What is your first impression of this view?
3.2) What is your thoughts about the information provided by this view?
3.3) In what ways do you see a connection to the gamification concept?
3.4) Is there something with this view you find confusing? If so, what and why?
Questions Regarding ”My Household”
4.1) What is your thoughts about being ranked?
4.2) In what ways do think this will influence user adoption of the gamification concept?
4.3) In what ways do you think this view can be improved?

Table B.1: Questions used in the expert evaluation.

C. Complete list of requirements

This is the complete list of all the requirements which is a product of all the CoSSMic workshops.

C.1 Non-functional Requirements

- Be able to display energy data (see table 1.3) related to the household, possibly outside of home.
- Be able to communicate with Agents and component controlling the devices, in order to control those and to know what their current schedule is.
- Documentation of possible device types and their respective setting ranges (regarding control rules or one-time operation settings).
- Be able to communicate with internet web services (example weather, tariffs, etc.).
- Support user authentication and different types of graphical interfaces depending on the user type.
- Interoperate with user and device registries.
- Support the user in the installation/deployment of the smart plugs to be monitored and link them to the device description.
- Access from outside or inside the (micro-grid) site.
- Access by mobile phone (android preferred), tablet and internet homepage via pc.

ID#	Source	Description
1	Konstanz	Graphical representation of the use or share of power/energy with detailed differentiation of sources. (always 100% view)
1.1	Konstanz	On the coloured labels include the actual energy amount by type of origin. [note for battery: charge on the right side and discharge as own use on the left side, yes it should be separated!]
2	Konstanz	Navigation links (or tabs) to other parts
3	Konstanz	Status table showing current load/use. Related to #1, the overall power load is the current use and is shown in the coloured bar on top (in this case approx 1kW red, 1,3kW blue, 1,2kW green).
3.1	Konstanz	Accumulated (consumed) energy is reset every day at midnight.
4	Konstanz	Battery load percentage (if battery is available).
5	Konstanz	Total kWh exchanged within CoSSMic since (starting date of trials) in blue.
6	Konstanz	Weather forecast per day including sun and cloud symbols (and if possible also fog).
7	Konstanz	Predicted PV performance based on weather forecast (12/18/24 hours ahead), including 6 (better 24) hours is ok of history to see how well the prediction was. May be in history screen comparison of last day's prediction vs. real weather with deviation.
8	Konstanz	Scheduled tasks overview per device that is scheduled. Include earliest/latest start and end parameters. Indicate once CoSSMic has started (time print) the device (for example with a green color).
9	Konstanz	Include a clock with current time.
10	Caserta	A larger top bar about various consumption/sharing.
11	Caserta	Enrich the chart about the prediction with a clear description and measurement units.
12	Caserta	Weekly forecasting instead of daily one.
13	Caserta	The schedule table should contain the past history (on day base) of consumption of devices until the present time and if possible also a part on the future assignment and schedule.

Table C.1: Requirements coming from Balsamiq and workshops on **Summary Screen**.

ID#	Source	Description
1	Konstanz	CoSSMic control indicates which device is currently controlled by the agent system.
2	Konstanz	Status control enables the user to give or withdraw the device from CoSSMic agent control.
3	Konstanz	Distinguish between single-run devices (dish washer, washing machine which have start and prospected end times) and constantly running devices. The first can be programmed to be controlled by CoSSMic per run.
4	Thomas V. (CoSSMic)	Perhaps split the table in single run and continuously running devices so it is clearer what is what.
5	Thomas V. (CoSSMic)	Single run device status should automatically change from ”not controlled” to ”controlled” when the rule is added (through ”get suggestions.”)

Table C.2: Requirements coming from Balsamiq and workshops on **Home Control**.

ID#	Source	Description
1	Konstanz	Only view one device (the one that was selected on the previous screen).
2	Konstanz	Input parameters for booking devices are somewhat device specific, depending on the settings (ref Settings).
3	Konstanz	CoSSMic should give feedback when the device cannot be booked using green energy.
3.1	Konstanz	If 3 is true, give the user the chance to either "approve" or "cancel" the booking.
3.2	Konstanz	For smart devices, the control will be automatically set.
3.3	Konstanz	For non smart devices, a suggestion to program the machine to start in 1, 2, 3, 6, 9 (depends on settings) hours is given. (washing machine clock is in control).
3.4	Konstanz	For devices that are allow to be started – power off is off- and automatically resume once the power is on (CoSSMic is in control). Power plug detects when the program is started manually by a current flow above a threshold value and knows: in use, CoSSMic cuts off the power (unless it should wash right now based on agent recommendation) and turns it on within the scheduled period based on agent recommendation.
4	Konstanz	Once the device is booked, it will be added to the summary page table (see Summary #8) and the status on the home control screen is also changed.
5	Caserta	Provide the functionality: Book in any case; Book only if CoSSMic power/energy will be available until the end of this task.
6	Caserta	Suggestion on when is more convenient to start a process.

Table C.3: Requirements coming from Balsamiq and workshops on **"Get Suggestions" screen**.

ID#	Source	Description
1	Thomas V. (CoSSMic)	Location of the system needs to be set (for the weather forecast, etc).
2	Konstanz	Priority should be possible to interlink with other devices. Example "When I turn on the stove –generating about 4kW of heat- in my kitchen, I want the heat pump to turn off".
3	Konstanz	"Add device" For the dishwasher and washing machine it must be possible to indicate the energy use and time use per program. These settings will then reappear when booking the device.
4	Thomas V. (CoSSMic)	Allocate a smart socket to the device (must also be able to change afterwards, for example in case of a malfunction, security-off).
5	Konstanz	eCar: type/speed of charge (expected time period) and demand of max/avg kW.
6	Thomas V./LW (CoSSMic)	Scheduling "show on summary page yes/no".
7	Caserta	Specify the priority in (High, Medium and Low). High priority means that the constraint will be bypassed and CoSSMic would address the schedule in any case, also if it means higher costs and/or non CoSSMic power use.
8	Caserta	Want to express the rules for the device with exact time or time slots or add complex rules on the data from other sensors (e.g. start the dryer only if is wet).

Table C.4: Requirements coming from Balsamiq and workshops on **"Get Suggestions" screen**.

ID#	Source	Description
1	Konstanz	Day/Month/Year view should be available for the overall use. Generation and use CoSSMic power and energy as well in different colors.
2	Konstanz	Day specific view needs to include icons for devices (also inspired by the link in 1).
3	Konstanz	As mentioned in summary screen #7: Comparison of the last day's prediction vs. the real weather conditions of the regarded day and with deviations. Earned kW vs. expected kW with time.
4	Caserta	Add a chart that indicates the credit and due of the users.

Table C.5: Requirements coming from Balsamiq and workshops on **History screen**.

ID#	Source	Description
1	Konstanz	Specific view of devices that are currently being used including their measured consumption (actual and total) and a total for all ones in use together.
2	Konstanz	Option for setting a maximum load at any time
3	Konstanz	For the passive devices indicate whether they can be used within a maximum load. Available Pmax and Emax, e. g. 7.4 kW and 3 kWh and the device needs 5 kWmax with 2.1 kWh, then it is ok.
4	Konstanz	When a passive device is turned on it will move to the active list
5	Caserta	Not set limitation on the power but limit and control the daily energy consumption.
6	Caserta	Enable the possibility to switch off the continuously working devices which are already active to give the place to other devices that are passive.
7	Konstanz	Already running single run devices must have priority over devices which are in an on duty waiting position

Table C.6: Requirements coming from Balsamiq and workshops.

ID#	Source	Description
1	Konstanz	The line manager always has full overview of used and unused devices and always has the right to switch off single ones after sending a "pop-up pay attention message" to staff personnel on their tablet and an execution time to switch off otherwise the line manager will do it by himself.

Table C.7: Requirements coming from Balsamiq and workshops.

D. CoSSMic: User-centred design and Lean Startup

User-centred design was conducted to make the system developed by the CoSSMic team relevant to the everyday lives of the end user. The idea behind user-centred design is to improve understanding of user and stakeholder roles in the development of complex systems [40][25][37]. In CoSSMic, user-centred design is characterized as a multi-stage problem solving process which not only requires designers to analyse and foresee how users are likely to utilize a product, but also to test the validity of their assumption habits with regard to user's behaviour in real world tests. Multiple methods were used in order to map expectations, needs, and attitudes. Such as *design workshops*, which incorporated a number of communication tools to encourage ideas and create discussions. These workshops used methods to develop rough prototyping, experience prototyping and product box. The aim was to get the users involved in the development of the software and technology that would be installed in their homes. Results were given to software and technology developers to assist in the development of parameters and concepts in CoSSMic.

During these workshops the organizers utilized the following methods: *Interviews* which were conducted in order to identify specific needs end users wanted from the system. The interviews focused on questions that lead to semi-open discussions to understand user expectation from CoSSMic. A number of *Innovation games* was used to develop paper prototype results which were used to get feedback on the functionality of the system. A *Business Model Canvas* was used to outline the business model with the goal of visualizing the value proposition of the project.

In CoSSMic they combined the Lean Startup with user and stakeholder involvement (UCD), and below are the three iterations conducted in CoSSMic based on Lean Startup product design that are derived from the workshops held in Konstanz and Caserta.

D.1 Workshop artefacts

The different interaction methods and games during the workshops resulted in these artefacts and examples.

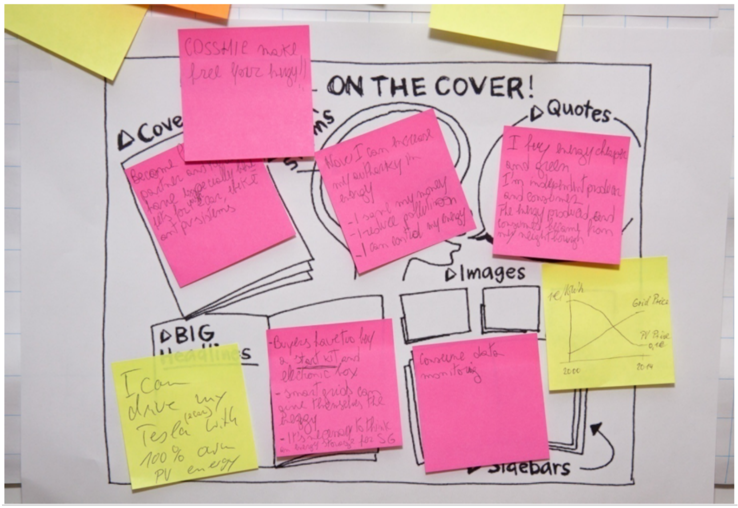

Figure D.1: Dashboard of an example Cover Story[40].

Figure D.2: Example of a product box[40].

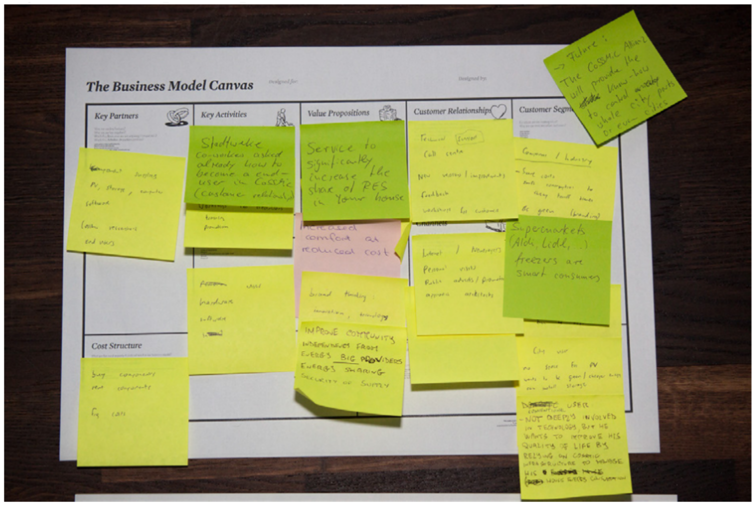

Figure D.3: Business Model Canvas[40].

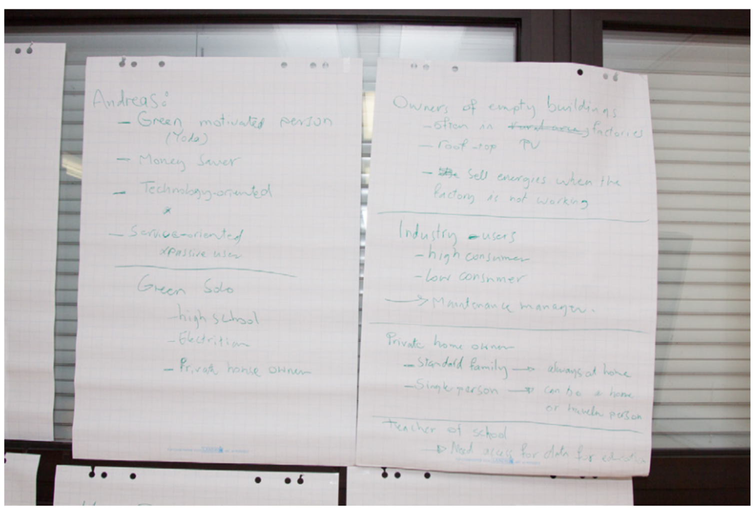

Figure D.4: Personas[40].

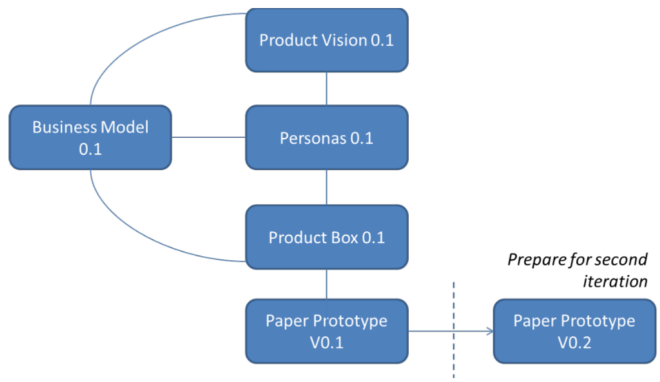

Figure D.5: First iteration artefacts[40].

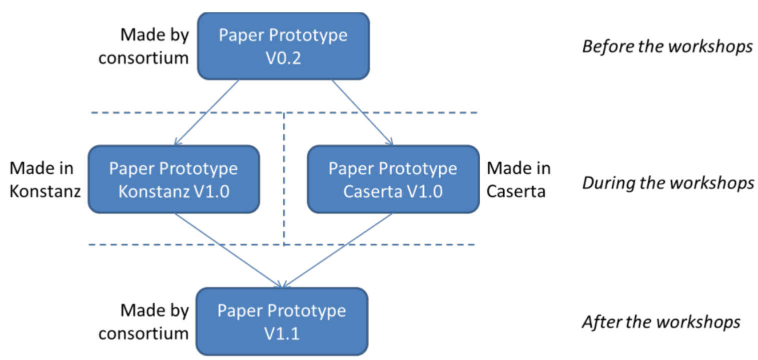

Figure D.6: Second iteration artefacts[40].

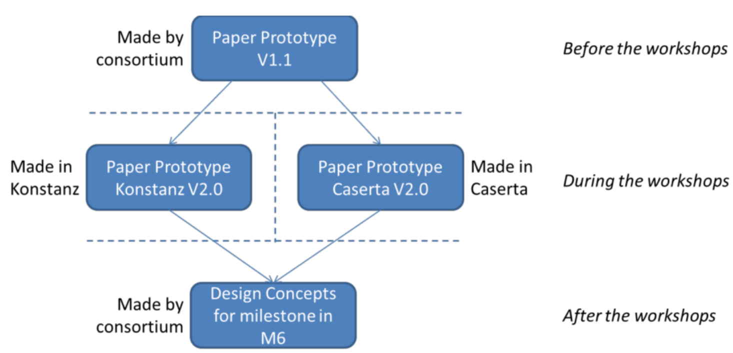

Figure D.7: Third iteration artefacts[40].

Bibliography

[1] Abrahamse, W., Steg, L., Vlek, C., and Rothengatter, T. "The effect of tailored information, goal setting, and tailored feedback on household energy use, energy-related behaviours, and behavioral antecedents", *Journal of Environmental Psychology, volume 27, pp. 265 - 276, 2007.*

[2] Albaina, I., Wisser, van der Mast, T., Charles, A.P.G, and Vastenburg, M. H., "Flowie: A Persuasive Virtual Coach to Motivate Elderly Individuals to Walk", *Proceedings of the 3d International ICST Conference on Pervasive Computing Technologies for Healthcare, 2009.*

[3] Allcott, H. "Social norms and energy conservation", *Journal of Public Economics. Volume 95, issues 9-10, pp. 1082-1095, 2011.*

[4] Biribakken, B. B., Bonsaksen, T. -H., Græsdal-Knutrud, L. E., Kanestrøm, P. Ø., Lian, H. H., and Lindkjølen, P. K., Student project, Group 16, IT2901 Informatics Project II. *Norwegian University of Technology and Science, NTNUI. Collaboration with SINTEF.*

[5] Consolvo, S., McDonald, D. W., Toscos, T., Chen, M. Y., Froehlich, J., Harrison, B., Klasnja, P., LaMarea, A., LeGrand, L., Libby, R., Smith, I., and Landay, J. A. "Activity sensing in the wild: A field trial of UbiFit Garden", *26th Annual CHI Conference on Human Factors in Computing Systems, CHI 2008, pp 1797-1806, 2008.*

[6] CoSSMic — Collaborating Smart Solar-powered Micro-grids (CoSSMic). `http://cossmic.eu/`.

[7] Clynes, M. P., and Raftery, S.E.C. "Feedback: An essential element of student learning in clinical practice", *Nurse Education in Practice, Vol. 8, Issue 6, Novemeber 2008, pp. 405-411*

[8] Darby, S., "The effectiveness of feedback on energy consumption", *A review for DEFRA of the litterature on metering, billing and direct displays, 2006.*

[9] Denny, P., "The effect of virtual achievements on student engagement". *31st Annual CHI Conference on Human Factors in Computing Systems: Changing Perspectives, 2013, pp. 763-772.*

[10] Deterding, S., Sicart, M., Nacke, L., O'Hara, K., and Dixon, D., "Gamification. Using game-design elements in non-gaming contexts", *29th Annual CHI Conference on Human Factors in Computing Systems, CHI 2011; Vancouver; Canada, 2011, pp. 2425-2428.*

[11] Deterding, S., Dixon, D., Khaled, R., and Nacke, L., "From Game Design Elements to Gamefulness: Defining "Gamification"", *15th International Academic MindTrek Conference: Envisioning Future Media Environments, MindTrek 2011; Tampere; Finland; 28 September 2011 through 30 September 2011; Code 89536, pp. 9-15, 2011.*

[12] Dobson, J., and Griffin, J. "Conservation effect of immediate electricity cost feedback on residential consumption behaviour", *7th ACEEE summer study on energy efficiency in buildings. American Council for an Energy Efficient Economy, 33-35.*

[13] Domínguez, A., Saenz-De-Navarrete, J., De-Marcos, L., Fernández-Sanz, L., Pagés, C., and Martínez-Herráíz J.-J., "Gamifying learning experiences: Practical implications and outcomes", *Computers & Education, Volume 63, pp. 38f0-392, 2013.*

[14] Efergy energy smart monitor. `http://efergy.com/`

[15] Ehrhardt-Martinez, K., Donnelly, KA., and Laitner, S., "Advanced metering initiatives and residential feedback programs: a meta-review for household electricity-saving opportunitie", *Energy 123, Report no. 6: 128.*

[16] Fehr, E., and Falk, A., "Psychological foundations of incentives". *European Economic Review, Volume 46, Issues 4-5, pp. 678-724, 2002.*

[17] Fischer, C. "Feedback on household electricity consumption: a tool for saving energy?", *Springer Science+Business Media B.V. 2008*, May 2008.

[18] Fogg, B.J., "Persuasive Technologies", *Communications of the ACM*, pp. 26-29, May 1999

[19] Fogg, B. J., "A behavior model for persuasive design", *Proceeding Persuasive '09 Proceedings of the 4th International Conference on Persuasive Technology article No. 40, 2009.*

[20] Fogg, B. J., "Persuasive technology: using computers to change what we think and do", *Magazine Ubiquity, Volume 2002 Issue December, pp. 89-120, 2002.*

[21] Foster, D., Lawson, S., Blythe, M., and Cairns, P. "Wattsup: Motivationg reductions in domestic energy consumption using social networks", *NordicCHI'10, Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries, pp 178-187, 2010.*

[22] Glatz-Reichenbach, J., Lindkvist, C, Vilarinho, T., Minde, A., Cretella, G., and Wienhofen, L. W. M. "End User Centred Interactive Software Architecture and Design: The Creation of Communities for a Smart Energy Use". *To be published at IEEE Xplore in the 15th International Conference on Innovations for Community Services (I4CS), July, 2015.*

[23] Hevner, A. R. "A Three Cycle View of Design Science Research", *Scandinavian Journal of Information Systems: Vol. 19: Iss. 2, Article 4, 2007.*

[24] Hevner, A. R., March, S. T., Park, J., Ram, S., "Design Science in Information System Reasearch", *MIS Quarterly Vol. 28, No. 1, pp 75-105, 2004.*

[25] Kubie, J. Melhus, L. A., Johnson, R. C., and Flanagan, G. A. "User-centered design", *IS Management Handbook: 7th Edition. CRC Press, Florida, 2000.*

[26] Magana, V. C., and Munoz-Organero, M., "GAFU: Using a Gamficiation Tool to save Fuel". *Intelligent Transportation Systems Magazine, IEEE,Volume:7 , Issue: 2, pp. 58-70, 2015.*

[27] Merriam-Webster dictionary definition of Gamification. Collected 13.06.2015. http://www.merriam-webster.com/dictionary/gamification

[28] Merriam-Webster dictionary definition of Feedback. Collected 15.06.2015. http://www.merriam-webster.com/dictionary/feedback

[29] Nicholson, S. "A User-Centered Theoretical Framework for Meaningful Gamification", *Presented at Games+Learning+Society 8.0, Madison, WI, 2012.*

[30] Petkov, P. Köbler, F., Foth, M., and Krcmarm, H. "Motivating Domestic Energy Conservation through Comparative, Community-Based Feedback in Mobile and Social", *Proceedings of the 5th International Conference on Communities and Technologies, pp. 21-30, 2011*

[31] Legris, P., Ingham, J., and Collerette, P., "Why do people use information technology? A critical review of the technology acceptance model", *Information & Management, Vol. 40, Issue 3, pp 191-204, January 2003.*

[32] Piccolo, L., and Baranauskas, C., "Energy consumption awareness in the workplace : tech- nical artefacts and practices Conference Item Energy Consumption Awareness in the Workplace : Technical Artefacts and Practices", *IHC'14, Proceedings of the 13th Brazilian Symposium on Human Factors in Computing Systems pp, 41-50, 2014*

[33] Rasul, I. and Hollywood, D. "Behavior change and energy use: is a "nudge" enough?", *Carbon Management, vol III, 2012, pp. 349-352.*

[34] Ryan, R. M. and Deci, E. L. "Intristic and Extrinsic Motivations: Classic Definitions and New Directions", *Contemporary Educational Psychology, vol. 25, pp. 54-67, 2000.*

[35] Ryan, R. M. and Deci E. L. "Handbook for Self-Determination Research", *Rochester, NY: University of Rochester Press, 2004.*

[36] Schultz, P. W., Nolan, J. M., Cialdini, R.B., Goldstein, N. J., and Griskevicius, V. "The Constructive, Destructive, and Reconstructive Power of Social Norms", *Pshycological Science, volume 18, pp. 429-434, 2007.*

[37] Shluzax, L. A., Steinert, M., and Katila, R., "User-centered innovation for the design and development of complex products and systems, *Design Thinking Research: Understanding Innovation. Springer International Publishing, Switzerland, 2014, pp. 135-149.*

[38] Smappe, "Understand your energy use, see the cost and save." http://www.smappee.com/be_en/

[39] Venkatesh, V., and Davis, F. D., "A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies", *Management Science 42(2): pp.286-204,.* http://pubsonline.informs.org/doi/abs/10.1287/mnsc.46.2.186.11926.

[40] Wienhofen, L. W. M., Lindkvist, C., and Noebels, M. "User-centered design for smart solar-powered microgrid communities". *14th International Conference on Innovations for Community Services (I4CS), pp 39-46, 2014.*

[41] Wilhite, H., Høivik, A., and Olsen, J. "Advances in the use of consumption feedback information in energy billing", *ECEEE 1999 Summer Study proceedings, Panel 3.*

[42] Winett, R. A., Neale, M. S., and Cannon , H. G. "Effects on self-monitoring and feedback on electricity consumption.", *Journal of Applied Behavior Analysis, vol. 12, pp. 173-184, 1979.*