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Field study on the application of persuasion techniques for energy reduction

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Graz, December 2015

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Abstract

Today's energy consumption problem concerns each and every one of us. This is the reason why it is necessary that whole nations deal with the issues of energy and sustainability to develop long lasting and future oriented solutions in order to reduce the overall energy consumption of their citizens. Consequentially, legal requirements were created for national grid providers. To satisfy those, the Carinthian grid operator 'Kärnten Netz GmbH' decided to cooperate in a research regarding this topic with the universities TU Graz, Alpen-Adria-Universität Klagenfurt and TU Delft. This cooperation was intended to persuade users to reduce their energy consumption. Together, an experiment was carried out, in which real customers were influenced by Persuasive Technologies in form of a, specifically for this experiment designed web application, in order to change their consumption behavior. For this purpose, so called 'Smart Meters' were installed in a certain test area. The test group, consisting of 303 households in this area, got access to the web application, and with it, to their energy consumption data. To evaluate the impact of the persuasive intervention, the electricity consumption data, and also the usage behavior on the web application were monitored via 'mouse tracking', allowing us to analyze the usage- and the consumption behavior of real customers under real conditions over several months. Results showed, that an intensive usage of the web application indeed led to a significant reduction of energy consumption. The present study therefore offered proof, that Persuasive Technologies are a suitable instrument to motivate consumers to reduce their own energy expenditure in a sustainable manner.

Kurzfassung

Die Energieproblematik der heutigen Zeit betrifft jeden einzelnen von uns. Gerade deshalb ist es so wichtig, dass sich auch Staaten kritisch mit den Themen Energie und Nachhaltigkeit auseinandersetzen, um langfristige und zukunftsorientierte Lösungsansätze zur Reduktion des Energieverbrauchs zu erarbeiten. Als Konsequenz wurden gesetzliche Vorgaben für nationale Netzbetreiber geschaffen bzw. in Kraft gesetzt. Um diese zu erfüllen, entschied sich die Kärnten Netz GmbH zur Forschungszusammenarbeit mit den Universitäten TU Graz, Alpen-Adria-Universität Klagenfurt und TU Delft. Ziel dieser Kooperation war es, KundInnen dahingehend zu animieren, Energie aus eigenem Antrieb heraus einzusparen. Gemeinsam wurde eine Studie durchgeführt, in dessen Rahmen reale KundInnen mit Hilfe persuasiver Technologien in Form einer eigens dafür entworfenen Webanwendung beeinflusst wurden, das eigene Verbrauchsverhalten zu verändern. Zu diesem Zweck wurden innerhalb eines Testgebietes flächendeckend Smart Meter installiert. Die Testgruppe, bestehend aus 303 Haushalten, erhielt Zugang auf die Webapplikation über welche die eigenen Verbrauchsdaten abgerufen werden konnten. Um die Auswirkung der persuasiven Intervention evaluieren zu können, wurden nicht nur der Stromverbrauch, sondern auch das Nutzungsverhalten innerhalb der Webanwendung mittels Mousetracking aufgezeichnet. Dadurch konnte das Nutzungs- und Verbrauchsverhalten von Stromkunden unter echten Bedingungen über mehrere Monate hinweg evaluiert werden. Anhand der daraus gewonnen Resultate konnte die Hypothese, dass eine intensive Nutzung der Webapplikation zu einer signifikanten Energieeinsparung führen würde, bestätigt werden. Die vorliegende Arbeit zeigt somit, dass persuasive Technologien durchaus ein geeignetes Mittel sind um EndverbraucherInnen zu veranlassen, den eigenen Energieverbrauch nachhaltig zu reduzieren.

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Acknowledgements

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Chapter 1

Introduction

This thesis is all about the analysis of a web application for the customers of an Austrian energy provider, called 'Kärnten Netz GmbH'. The intended purpose of this application to invoke more conscious and sustainable usage of energy.

1.1 Smart Meters

Since years the European Union has pushed the usage of smart meters and they will become mandatory in Austria [IME-VO, 2012] in the future. This was the reason why the development of the web application was necessary.

The technical term of smart metering is defined as the computer-aided measurement, ascertaining and controlling the energy consumption and supply. Companies and private households (smart homes) are on the same level of pertinence. Smart meters are electronic networked meters to measure the in- and output of resources and different types of energies such as water, gas and electricity. Those meters are part of the so called 'smart grid', an intelligent power grid, primarily, because they also contain in- and output devices, as well as web applications. All collected and logged data will be transferred to a measurement services provider [Bendel, 2015].

It is commonly believed that, due to usage of smart meters, consumers will get access to additional data about their own energy consumption behavior, which should make them more conscious about their energy usage. The Austrian prescription dictates not only the region-wide installation of smart meters, but also the provision of a web application, so that the user can monitor his/her own consumption data [DAVID-VO, 2012].

Due to the electronic acquisition of data, it is possible for the grid provider, as well as for the consumer, to have their data evaluated and analyzed in real time. The advantage for both sides are obvious: On the one hand, consumers have the possibility to receive details of their own consumption behavior for the first time, and thus are able to identify problems related to their energy consumption. On the other hand, the grid provider, if he has the permission of the consumer, is allowed to calculate a detailed consumption analysis. This leads to an optimization of energy consumption and of the required load management, which may increase the efficiency of the smart grid as a result.

The success of smart meters hinge on the balance between optimizing the energy network and maintaining data privacy [Cuijpers & Koops, 2013]. At present days, this is still a gray area. The consumption data allows to draw conclusions about the customers habits, but also it prompts questions about information ethics.

1.1.1 Gateway for the experiment/Motivation

The grid provider not only has to abide the aforementioned regulations [DAVID-VO, 2012], but also has the obligation to impart his customers a sustainable handling of energy. Expressed in numbers, each grid provider has to achieve an overall ongoing energy reduction of 0.6% per year averaging over all its customers [EEffG, 2014].

To develop a web portal, which fulfills all the requirements of the customers and also the requirements of the legislator, tests are necessary. Therefore two test areas were defined and two installations were made to this day.

The first test area was located in a rural area close to Ferlach, Carinthia. Smart meters were installed in all households and companies in a specific area. Also a web application was provided to these consumers. One problem was that after only six months very few accesses to this web application were logged.

The second trial instance was located in a more urban environment, compared to Ferlach in the so called 'Smart City Villach'.

The 'Smart City Villach' project is a long-term project on social, economic, technological and ecological innovations for the city of Villach in Carinthia. In the Villach area many projects in the field of energy reduction are located. The increase of energy efficiency is, besides zero carbon production, resource efficiency and quality of life, a major goal in this long-term project [Villach, 2013].

Smart meters were installed region-wide, but this time the energy provider initiated a cooperation for the design of the web application with a young Carinthian start-up company and a consortium of universities: University of Technology of Graz, Alpen-Adria University Klagenfurt and University of Technology Delft (Netherlands). The goals of the energy provider and also for the universities were, (1) to increase the usage of the web portal, and (2) to persuade customers to decrease their electricity consumption.

1.1.2 Research Questions

The research objective is to develop a web application aimed at reducing the energy consumption of households, based on methods of Persuasive Technology. To be able to do so, it is necessary to understand how these applications are used. This leads to the main research question of this thesis:

How does detailed consumption information impact energy consumers in their individual power usage behavior?

The information is provided through a web application. To be able to answer the main question, it has to be asked why the application was used (intention), how it was used (intensity) and which type of information processing method is needed. Therefore, further research questions are:

- **How do consumers interact with a web application providing details on their energy consumption behavior?**
- **How does a user's attitude towards renewable energy influence their usage of online the information system?**
- **Does the intensity of usage influence the energy consumption behavior?**
- **Does a persuasive intervention in form of a social ranking have an effect on the user's energy consumption?**

1.1.3 Procedure of the Experiment

To achieve an impact on a user's behavior and therefore on his/her energy usage, we have to provide information in a particular way. The methodology of affecting a user's behavior in the human-computer-interaction is called 'Persuasive Technology'. The basic principles will be explained in Chapter 2. Also, examples from past research in the field of energy reduction in combination with Persuasive Technology will be discussed. This research was needed to develop a web application that could answer the research question. As already mentioned, this thesis is based on an industrial work. Due to that, some limitations had to be accepted. Chapter 2 can be seen as an explanation of the fundamentals for working with Persuasive Technologies and a set of examples and ideas on how to use them. However solely this knowledge did not lead directly to the design of the online information system, because it also has to fulfill the requirements for the customers of the energy provider.

Chapter 3 explains how the data was collected from the users. To explore the usage and interaction of the web application, a survey was developed, and 'mouse tracking' was implemented, which tracked the mouse-coordinates and mouse-movements on the web site. The hereby generated data allows the aforementioned analysis of the users intent. The consumption data was also tracked, with the installed smart meters. In order not to risk any private data protection issues, all households received proper information about the experiment. In the end, 303 out of 530 households and companies agreed by a declaration of consent. The design and implementation of the web application was broken up into two parts. The first stage included the implementation of all important base functionalities of the web application. The second stage was to extend the web portal with a persuasive intervention component, the so called social 'ranking'. The 'ranking' is the method that should affect the user to improve his/her energy consumption behavior, by responding to social and personal aspects. The intention of the ranking was, that a private household can compare its own consumption with other households in their direct neighborhood. Also, gamification mechanisms, for example the possibility to see a personal rank, were integrated into the system.

Chapter 4 explains the design and the intervention in detail, and therefore deals with the work, that was done for this thesis, besides the evaluation of the data. Main issues were the specific proposals for the design of the web application, the quality assurance of the project, and thus also parts of the project management and as already mentioned the evaluation in the end. Finally, the collected data from both parts of the experiment were preprocessed, as further discussed in section 5.1 and section 5.6, and afterwards analyzed with different methods. These evaluations are partitioned into three thematic blocks: population (section 5.1), behavior (section 5.5) and consumption (section 5.6). These sections will explain, who used the web application, how the web application was used and how the consumption behavior evolved.

Chapter 2

Persuasive Technologies in Energy Domains

2.1 Persuasive Technologies Basics

Persuasive Technologies can be defined as “any interactive product designed to change attitudes or behaviors by making desired outcomes easier to achieve” [Fogg, 2002, p. 15]. Fogg defines persuasion itself as “an attempt to shape, reinforce, or change behaviors, feelings, or thoughts about an issue, object, or action” [Fogg, 1998, p.225].

As mentioned, persuasion deliberates a choice to manipulate the user. There can be two intentions to persuade: profit or social. Of course, many ethical issues exist regarding the usage of Persuasive Technologies [Davis, 2009]. Even though Persuasive Technologies are normally used for good intentions, such as reducing energy consumption, this is not always the case. Additionally the usage of Persuasive Technologies include monitoring the users in their private parts of their lives, as for example in this work, in their own homes. The methods should therefore be used in a sensible way, otherwise they could even result in the opposite of what was intended (as exemplified in the case of Breakaway [Jafarinaimi *et al.*, 2005]).

Persuasive Technologies change the way we use technical devices, from a normal tool to a supporting instrument for moral queries [Spahn, 2012]. However, every communication, human or non-human, affects a person and that is the reason why we have to understand the techniques, possibilities and weaknesses of this technology.

Nowadays communication shifts from standard human-interaction and one-side information pipe to an interactive, bidirectional and omnipresent information exchange. Web applications and Apps play an important role for this new type of communication. It also offers new possibilities to affect the usage and to influence people who are using the applications.

One of the first authors who described effects and methods in the area of Persuasive Technologies was, as already mentioned, B.J. Fogg. In his book "Persuasive technology: using computers to change what we think and do " [Fogg, 2002] gave an overview of the methods and the underlying psychological effects which are used.

2.1.1 Preconditions

Usability and Credibility are necessary preconditions to be able to apply persuasive methods. Usability is essential to get the user-acceptance for the software [Pribik & Felfernig, 2012] because the psychological effects are often underlying and only effective if the functional use-case is fluent. An Example: If a click on a Button directs someone to an error, or the text could not be understood by the user, the user could believe that the operators are not trustworthy and therefore have doubts about their integrity.

Thus, usability can be seen as a part of credibility. According to [Fogg, 2002] credibility always refers to the perceived credibility of the user. There has to be a distinction between perceived trustworthiness and perceived expertise. Hence the person has to believe that the information and the application is truthful, fair and unbiased. Expertise can be seen as the sum of apprehended competence, knowledge and experience. A comprehensive user study reinforces this assumption. The paper [Fogg *et al.*, 2003] was a study with about 2500 people which explains what credibility of websites means to them. It turned out that the majority focuses on the design of a web application: The entirety of color theme, layout, images and typography has a huge impact on the users "look and feel". The other two important aspects are structure and focus of information. The information on a website has to have a good and easy structure and has to focus on a specific topic such that users are not overloaded by information. The usefulness, accuracy and the bias of information were often noticed as well. Furthermore, the preparation of information has a central influence on credibility [Tanaka, 2010]. Other supporting points are motive, reputation, recognition and advertising of the owners. Many papers show that Familiarity, Credibility and Trust are important for users [Lowry, Roberts & Higbee, 2007] and are necessary if the initiator wants them to perform certain actions on the website e.g. a bank transaction [Gefen, 2002].

2.1.2 Types of Behavior Changes

There are many different types of behaviors, and it is commonly believed that applied persuasive methods should be differentiated and adapted to specific behaviors. To this end, Fogg invented the behavior grid [Fogg, 2009]. The idea behind the behavior grid is: "to create a more efficient way to study and design for various types of human behavior" [Fogg, 2009, p. 1]. In this grid model the behaviors are categorized by time-period (one-time, a designated period of time, or else the effect of the change should last from this specific point in time on wards) and type of the behavior (new, familiar, increasing, decreasing and stopping). The different classifications are shown in 2.1.

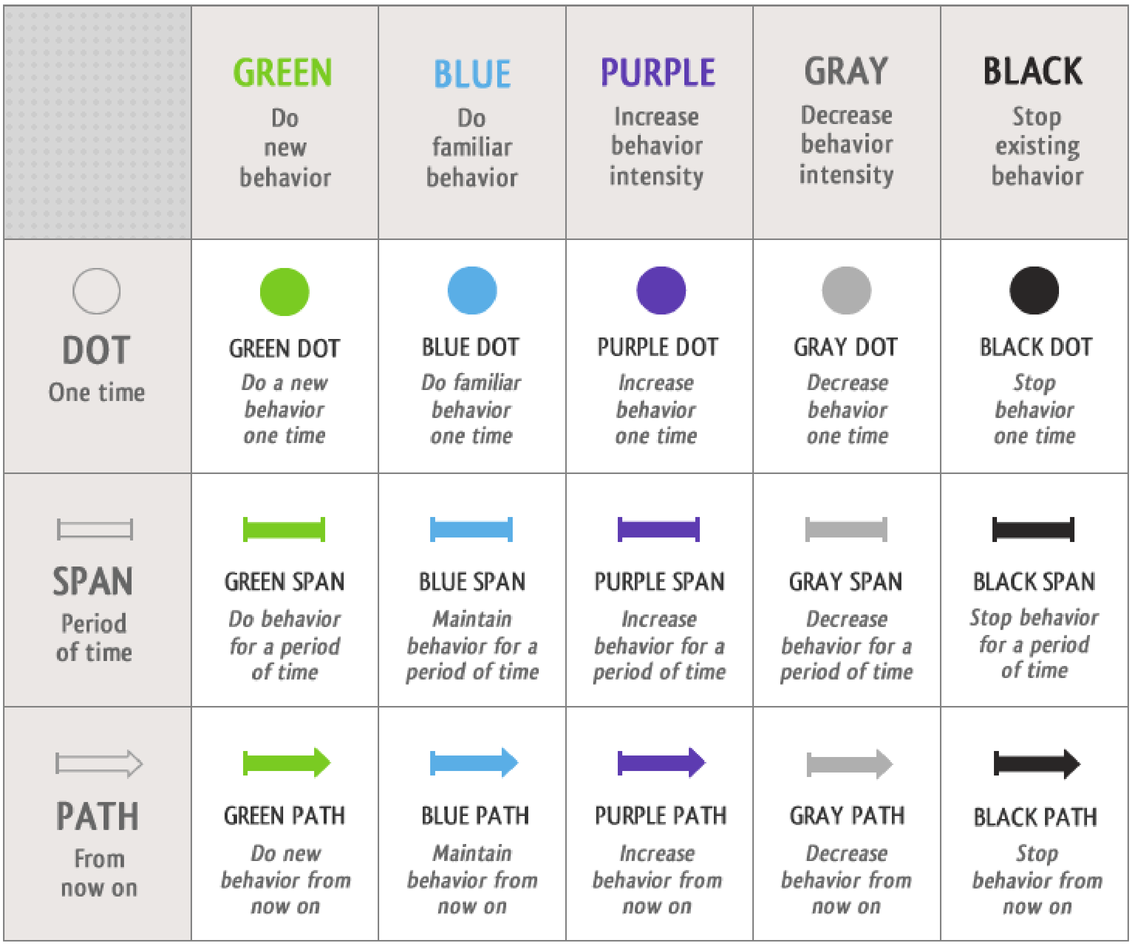
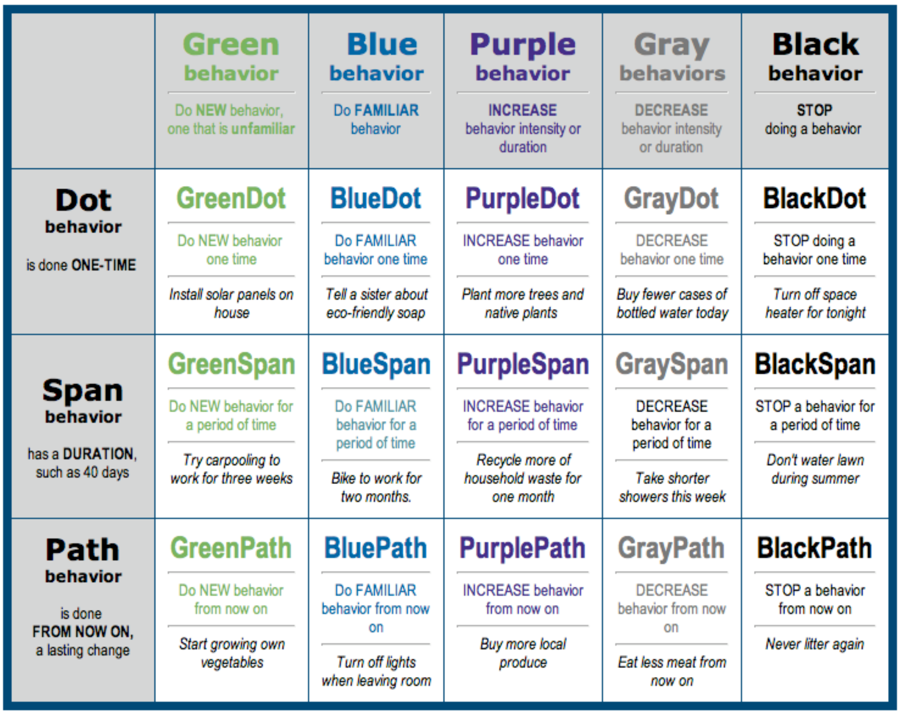


Figure 2.1: Behavior Grid, source: [Fogg, 2015b]

The attraction of the behavior grid approach is that it allows for tailoring the method to every action a user made. As is noted on the web application for the behavior grid, the behavioral repertoires captured in the grid are:

1. Learn about a specific type of behavior change.
2. Create solutions for achieving that behavior.

Figure 2.2 summarizes and provides several examples. A person can for instance conduct a familiar behavior (a so-called 'blue' behavior) once (so-called 'dot' behavior). In that case, the inhibition level is very low. It is often sufficient to initiate rather than to support it over a long time or to motivate it. To achieve new behavior over a period of time you have to motivate the user, so they think about adopting this new behavior, you have to lead them for a certain amount of time to keep them motivated, so that finally they take over the behavior without questioning it anymore.



	Green behavior Do NEW behavior, one that is unfamiliar	Blue behavior Do FAMILIAR behavior	Purple behavior INCREASE behavior intensity or duration	Gray behaviors DECREASE behavior intensity or duration	Black behavior STOP doing a behavior
Dot behavior is done ONE-TIME	GreenDot Do NEW behavior one time *Install solar panels on house*	BlueDot Do FAMILIAR behavior one time *Tell a sister about eco-friendly soap*	PurpleDot INCREASE behavior one time *Plant more trees and native plants*	GrayDot DECREASE behavior one time *Buy fewer cases of bottled water today*	BlackDot STOP doing a behavior one time *Turn off space heater for tonight*
Span behavior has a DURATION, such as 40 days	GreenSpan Do NEW behavior for a period of time *Try carpooling to work for three weeks*	BlueSpan Do FAMILIAR behavior for a period of time *Bike to work for two months.*	PurpleSpan INCREASE behavior for a period of time *Recycle more of household waste for one month*	GraySpan DECREASE behavior for a period of time *Take shorter showers this week*	BlackSpan STOP a behavior for a period of time *Don't water lawn during summer*
Path behavior is done FROM NOW ON, a lasting change	GreenPath Do NEW behavior from now on *Start growing own vegetables*	BluePath Do FAMILIAR behavior from now on *Turn off lights when leaving room*	PurplePath INCREASE behavior from now on *Buy more local produce*	GrayPath DECREASE behavior from now on *Eat less meat from now on*	BlackPath STOP a behavior from now on *Never litter again*

Figure 2.2: Behavior Grid Examples, source: [Fogg, 2015a]

2.1.3 Persuasive role of computers

Persuasive Technologies can work theoretically, but this section examines an important boundary condition: the different "roles" a computer can adopt to persuade. As already determined, people are generally not able to fully deny persuasion. The question now is, how it should be done and which type should be used. First of all, we will define the roles a computer or software could assume, and observe the specific methods which can be used. Therefore, the next sections will focus on different roles a computer can take on: social actor, tool and/or medium [Fogg, 2002].

2.1.3.1 Social Actor

The computer should intend a social connection with the user, and such as influence people by giving personal and real-time feedback. [Suchman, 1998] claims that a computer should make this connection as a pipeline for social feedback like twitter and facebook. Some researchers go beyond that assumption and believe that computational agents can motivate people to save energy in their homes [Mahmud *et al.*, 2007]. These agents can be seen as direct social actors, and the more friendly and the more competent the agent is, the better the performance of energy savings. In another study it was shown that negative feedback from the intelligent social actor has even more influence [Ham & Midden, 2010a].

2.1.3.2 Tool

In the role of a tool, a computer represents a gadget to increase performance and effectiveness of an individual or a group. In this case, improvement roots from information and guides an application provided to its users. The aim is to motivate by providing help and assistance to simplify everyday work. Typical examples for this kind of role are calculators or MS Outlook ™ [Fogg, 2002].

2.1.3.3 Medium

In the role of a medium a computer motivates the user by executing additional stimulating events. The information is sometimes wrapped in games or films, providing a playful way to learn for the user [Kapp, 2012]. Learning and understanding should be easier and therefore good behavior will be supported and consolidated. There are rudimentary cases like color assistance (Colors indicate how the user has recently made progress towards the goal, [Kientz *et al.*, 2010]) or very complex application, for example learning games [Ruggiero, 2014].

2.1.4 The seven Persuasive Principles for Tools

As already mentioned this thesis' focus is on persuasion in the context of applications serving as tools and mediums. For this reason it is necessary to take a deeper look at the principles Fogg built up for tools [Fogg, 2002, p.31].

- Reduction: Software should be as simple as possible. The design should be reduced to its main functionality, and be straightforward and intuitive for usage.

- Tunneling: Tunneling refers to “guide a user through a complex experience and persuade along the way”[Torning & Oinas-Kukkonen, 2009]. Software then additionally operates as a guide or wizard [Purpura *et al.*, 2011].

- Tailoring: Tailoring means that the software revises the information individually for every single user. Typical web applications are MySpace-sites, where a user is able to build the site based on their own needs and impressions.

- Suggestion: To give advice in the right place at the right time is an important and difficult task [Andrew, Borriello & Fogarty, 2007]. A typical representative of this kind of systems are navigation-systems, such a system for instance gives jam-warnings or location based point-of-interest information.

- Self-Monitoring: The users monitor themselves, because of the motivation to change something in their own behavior to reach a personal goal [Zapico, Turpeinen & Brandt, 2009]. Direct feedback in this context is a strong persuasive mechanism [IJsselsteijn *et al.*, 2006], often used for health-applications, for example: tracking your food to reduce weight.

- Monitoring: For monitoring, the surveillance happens from the outside, and with the aim of changing the behavior with feedback given from outsiders. Like health applications, monitoring is commonly used among others in medical monitoring by doctors.

- Conditioning: This persuasive effect is part of behavioral psychology [Pavlov, 1897, 1902] and has well known effects [Reeve, 1997]. When applied this principle, right behavior will be supported and honored. This effect increases when bad behavior is punished [Skinner, 1938],[Nakajima & Lehdonvirta, 2013].

Because of the energy focus in this work, the purpose of persuasion is reduction, because to save energy could be seen in this context as reduction [Ferebee, 2010]. Ferebee’s research focuses on papers that investigate the behavior reduction or even the behavior cessation in context of Persuasive Technologies. Therefore the author evaluated 24 articles and mapped them onto Foggs Behavior Grid. The studies which were part of her work had to fulfill certain criteria: behavior reduction as primary purpose, the use of Persuasive Technology, positive findings, furthermore it had to be a personal behavior that should have changed, and the paper had to report empirical results. Afterwards the papers had been categorized through GBG (decreasing level), FBM (factor used to effect change: motivation, ability or trigger) and their Persuasive Strategy, which are already defined above. With this she identified two predominant paths for a successful behavior reduction. First: periodical interventions with triggers as factor and suggestion as persuasive strategy, and second: interventions on signal (behavior change) with motivation as factor and self-monitoring or personalization as persuasive strategy.

2.2 Energy conservation with Persuasive Technologies

Energy conservation is one of the biggest research-fields of persuasive technologies [Ferebee, 2010], [Hamari, Koivisto & Pakkanen, 2014]. Causing many different fields to deal with the problem of energy reduction.

A typical ambit is mobile and desktop application design. A very thoroughly researched implementation is EcoIsland [Kimura & Nakajima, 2010]. The challenge is to influence users to save energy not only for personal reasons, but also for group or public benefits. The idea is to visualize the problematic nature of CO^2 emissions. Therefore the group of household members who are represented by avatars are set on a virtual island, see Figure 2.3. The levels of CO^2 emission are represented by the increasing sea level around the island. The more CO^2 emissions the household produces, the more the island sinks into the sea. The sea level stays the same or is shrinking if the self-set aim of reduction can be held by the family members. To measure the savings, the users have to report their behavior. Examples are reducing energy by turning down the air heater or taking the train instead of the car. The visualization and the whole concept is grounded in 5 (persuasive) design strategies: Organizing Groups, Anonymity, Mutual Surveillance (Monitored by Others, Watching Others, Comparing with Others), Development of Mutual Aid and Combined Use of Positive and Negative Feed backs. The conclusion of the researcher was: "We extracted five design strategies for persuasive applications that promote public interests in collectivist societies. From our experiment, we discovered that mutual surveillance and positive and negative feedback worked. Also our design made users feel closer to the environmental protection with using virtual assets and EcoPoints themselves especially in the early stage." [Kimura & Nakajima, 2010, p. 706].

Figure 2.3: EcoIsland, source: [Kimura & Nakajima, 2010]

Another application is the EnergyWiz [Petkov *et al.*, 2011]. Its focus was on the different ways in which persons can be motivated to save energy. People also have converse types of comparing themselves or comparing themselves to others. The reason the researchers built the application was the gap in the literature concerning how energy-related comparative feedback should be designed. The authors applied two main motivational concepts taken from psychology: feedback and comparison. Additionally the pro-environmental attitude of the users was ascertained. Feedback is a basic and proven concept. A focus of the paper lies on the various types of comparison: Explanatory Comparison, Temporal Comparison, Social Comparison, Normative Comparison Feedback, One-on-one Comparison Feedback and Comparison by Ranking Feedback, which were defined by [Petkov *et al.*, 2011].

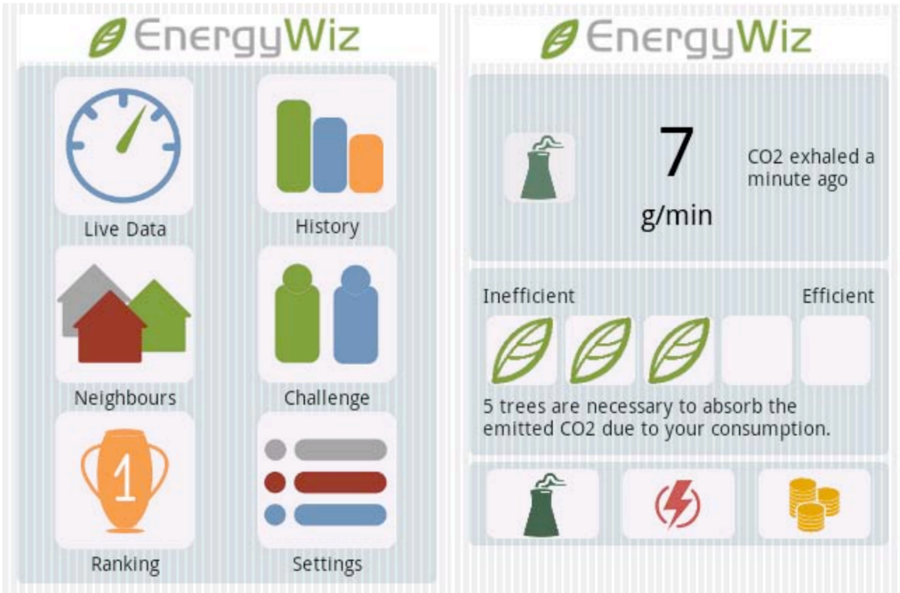


Figure 2.4: EnergyWiz Main Menu and Live Data, source: [Petkov *et al.*, 2011]

The application design was modern and colorful (Figure 2.4 and Figure 2.5), and the users got real-time feedback on their energy consumption. For the five types of comparison, five different sites were created (except of the main menu) to be able to measure the impact of influence of these various types for single users: Live Data, History, Neighbors, Challenge and Ranking.

For the evaluation of the application 17 users participated, 14 of them were male. The interviews took place in two steps, the first of which was the application walk-through with certain little tasks to get familiar with the app. The second was an open but structured interview, where the users were asked about all types of comparison, the feedback of the app, their attitude but also their feedback for the application. The qualitative survey had some interesting annotations from the users. "[...] it is a challenging task to find two identical households whose comparison will provide undisputable foundation for realistic comparison since even similar families in identical homes might have different appliances and lifestyles. " [Petkov *et al.*, 2011, p. 28]. This phenomenon was mentioned by many users. For the comparison, the participants prefer friends rather than similar households or neighbors. Hints how to save energy were missing, and therefore the last step to go was absent. In conclusion it should be said that there is a lack of a quantitative feedback.

Another field of research describes the effect of ambient persuasive lighting [Ham & Midden, 2010b]. It shows the positive effect of ambient lighting in contrast to factual feedback. It was a laboratory-experiment, but the two participant groups got either color support or factual feedback in form of kWh consumption, instead of different colors. Also there were stronger persuasive effects with color-support, which reduced the energy consumption approximately by

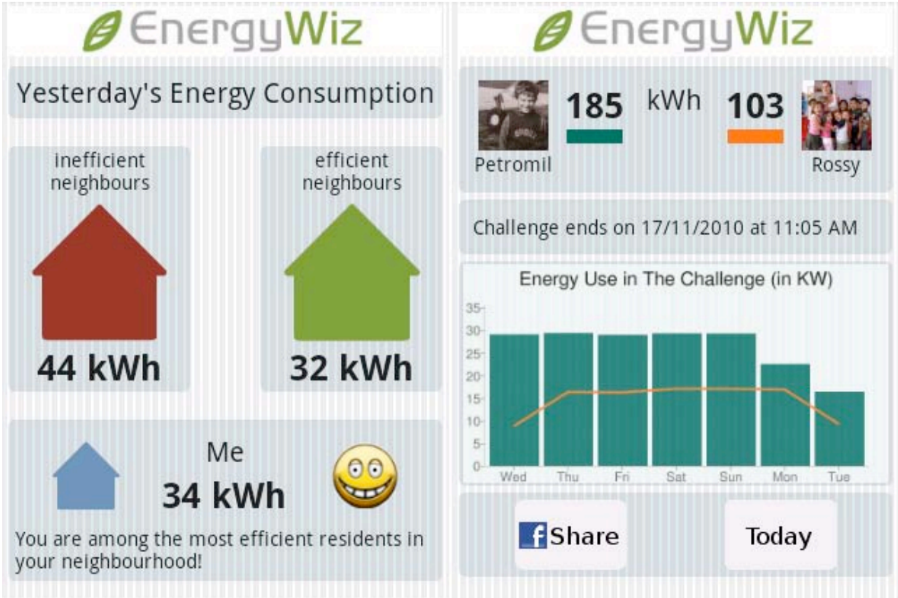


Figure 2.5: EnergyWiz Neighbours and Challenge, source: [Petkov *et al.*, 2011]

27 %.

The paper [Lu, Ham & Midden, 2014] follows the work of this research group. Like in the previously described paper they gave a description of a lab-study in which the participants sat in a simulated home where they saw how much energy they are actually using, underscored with specific light colors (red/violet for high, green/yellow for low energy consumption). The hypothesis was that stronger colors related to energy consumption have a better persuasive effect, in this case red-green. The effect was confirmed in the study. Additionally, a cross-culture effect was investigated (Dutch and Chinese participants), but no differences relating were found.

Another way of persuasion is an ongoing, permanent way of influencing with mobile devices. The work of [Gamberini *et al.*, 2012] focuses on Gamification with smart devices to support energy awareness. In the mobile game called EnergyLife, tailored feedback and action-based hints (triggers of exceptional use) aiming for increased user awareness for energy conservation in their own household. In this game sensors were installed in households and an app provided information, tips and little games for the user. To get participants used to it, the single functions got unlocked one by one when they reached a next level. 16 people participated in the study, out of which at least every second user belonged to a different household. The duration of the study was about 4 months. During this period the households were supervised. The authors showed that they were able to reduce the energy consumption of the participants. Another outcome was that the participants where not annoyed by repeated tips. The app was often used at the beginning (about 8 logins per day), but the rate of logins decreased to an average of one per day.

2.3 Problems in former scientific work

A review including 95 papers which focused on Captology, Persuasive Technology and Gamification showed the most common pitfalls in the literature [Hamari, Koivisto & Pakkanen, 2014]. The papers needed an empirical study, the research methods had to be made explicit, and include a description of the Persuasive Technologies used. Additionally they also had to investigate these stimuli: the psychological outcome as well as the behavioral outcome in some sort of combination. Out of all papers, 52 had positive and 36 partially positive outcomes. The main type of studies were quantitative and therefore surveys or trackings were used. The psychological outcomes focused mainly on engagement (28), motivation (24) and awareness (21). The target behavior was health (45) followed by energy consumption (20). The authors criticized several pitfalls in literature: 1) sample sizes of participants were very small (average 26), 2) some did not use validated scales, 3) some had a lack of control groups, 4) the systems were investigated as a whole instead of focusing on the particular effects, 5) only descriptive statistics, 6) the time-frame of the experiment was often too short and 7) the lack of clarity in reporting the results.

2.4 Research model

As already mentioned in section 1.1.3, this thesis is based on a practical study, and therefore some limitations and restrictions, for example time, company culture or financial resources, had to be considered during the setup of the thesis. This is also the reason why the first half of this chapter describes the fundamental techniques and preconditions which were required to set up a motivating information system. The second half of this chapter describes a set of ideas and practice examples for the design of the web application. In the scope of this work it was not possible to base the whole design or experiment only solely on research needs. Also, corporate and legal specifications had to be served.

Nevertheless the research potential of such a project is very high and the research question could be answered under real conditions. Therefore the sub-questions from section 1.1.2 will be answered.

The first question 'How do consumers interact with a web application, that provides details on their energy consumption behavior?' will be answered by analyzing the user's behavior during the visit of the web application. The focus lies in the question, which information design the user is most interested in. Accompanying this, further points of interest are the questions, which features of the information systems were not used at all, and how these findings can help to support the subsequent analysis of the data.

The remaining questions need the following key values to be answered: attitude, intensity, rank and consumption. It is often assumed in literature, that existing attitudes of users can have an impact on his/her behavior [Petkov *et al.*, 2011]. Renewable energy is an important topic in Austria, many power companies even advertise it [E-Control, 2015]. In the first hypothesis (H1) it will be evaluated, if the attitude towards renewable energy has an impact on the user's handling of his/her own energy consumption. (H1): 'The attitude of a user towards renewable energy influenced the intensity of activities on sub sites'

The quantification of the usage of the online information system will be defined as intensity. The second research question mentions this: Does the intensity of usage influence the energy consumption behavior? The following hypothesis (H2) is extracted from this question: 'Intensive usage results in higher energy reduction'.

To conclude the research model in this thesis, the last sub-question is asked: 'Does a persuasive intervention, like a social ranking, have an effect on the user's energy consumption?'. It is assumed that Persuasive Technologies help to change behavior [Fogg, 2002].

The aforementioned question provides the base for two further hypotheses. One refers to the energy consumption (H3) and the other quantifies, how efficient the persuasive method worked (H4). (H3): 'The duration of a session decreases in stage 2'. (H4): 'The ranking has an impact on the consumption'.

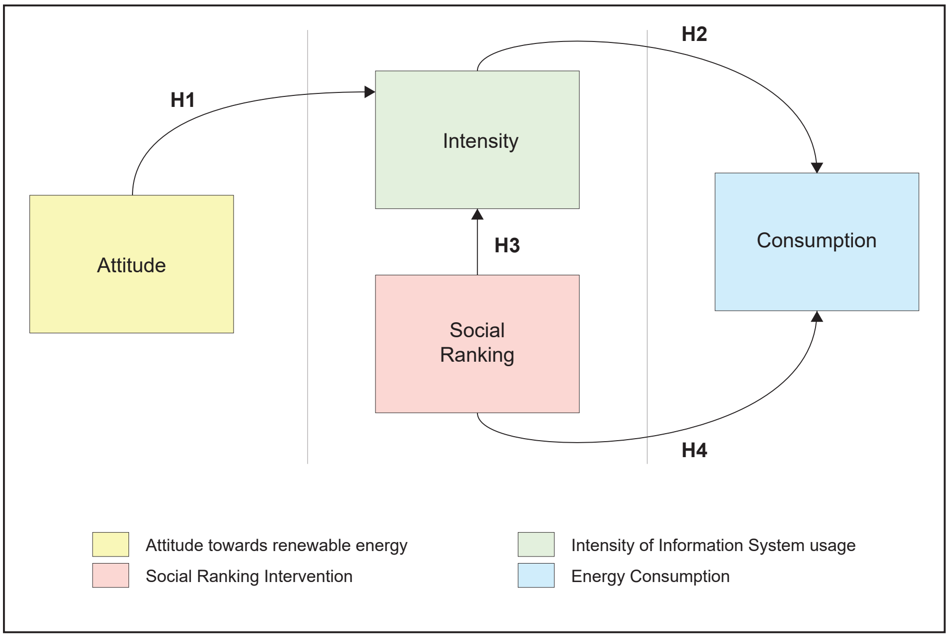


Figure 2.6: Research model

This completes the research model that can be seen in 2.6. Alongside the hypotheses test and the analysis of the population, also the behavior on the information system was analyzed, but this time in an explorative way. The results will be presented in Chapter 5.

Chapter 3

Research Design

Due to the complexity of such a big project, several pages are devoted to explaining the methodology. In addition to the important subsections 'participants', 'procedure' and 'variables', also the procedure in the background will be explained.

3.1 Participants

All participants lived in a small area of the 'Smart City Villach'. The participation was voluntarily and the people did not get a reward for it, neither for participating the survey nor for the web application. However, an incentive was given in form of a lottery. Among all users, who visited the information system, a prize was drawn (a voucher for a local restaurant). It was assumed, that most of the user's native language was German, although there was no specific question in this respect. The population consisted of all ages, education-levels, household-sizes and genders, as can be seen in section 5.1. Following, is an explanation of these demographic criteria. It will be needed later in the analysis.

3.1.1 Total population

Overall there exist 530 households and companies within the test area. Out of these, 306 gave a declaration of consent to participant in the research experiment. For this thesis and especially for the next sections, the total population is set to 306 users. Only those users could be integrated in the project because the analysis only is in direct relation with the use of the web application. For the time being the demography of all people living in the test area will be examined, to get an overview of the test population.

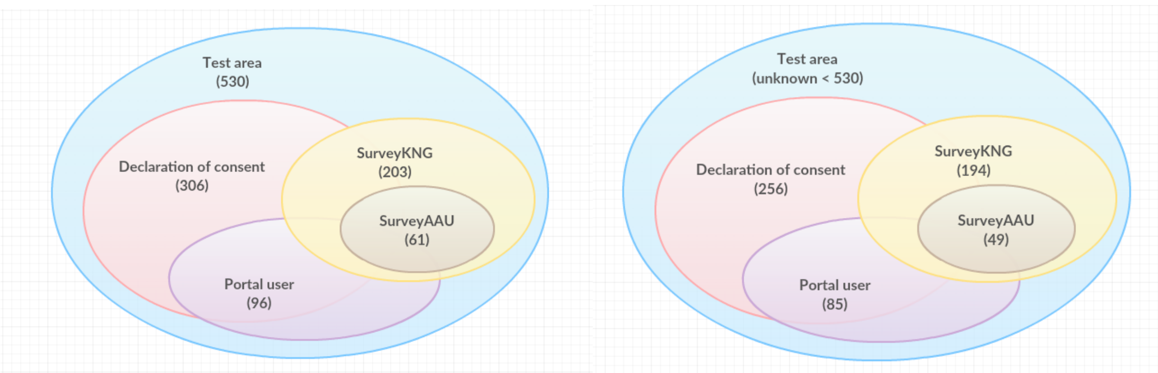
As already mentioned, only private households have been examined. Furthermore, the project stakeholders defined, that the requirements of business clients are not going to be part of the examination at the beginning of the experiment.

From a total of 203 participants of the KNG survey there were 194 private persons. Out of those 194, 59 gave their declaration of consent and also visited the web application. Subsequently, the population will be examined, regarding the user's demographic structure in the test area (gender, education, age, technical skill and household size). Also, a difference between partial groups, regarding the frequency of web application uses, was searched after. It has to be emphasized, that 85 out of 306 are private participants with declaration of consent visited the web application at least once. 26 of these participants were not part of the KNG survey, because some of them did not live in this area at the start of the experiment. They moved into their apartment at a later date.

The following two Venn diagrams 3.1, show and define the names of the populations, and their relations to each other:

- Test area (all households in the test area),
- Declaration of consent (all households which gave a declaration to the research experiment),
- SurveyKNG (all households, which took part in the elicitation in Autumn 2014),
- SurveyAAU (households, which took part in the elicitation in Autumn 2014 and also took part in the additional survey, as described later on) and
- Portal user (households, which visited the web application at least once)

  (a) for the total population including the industry,
  (b) only private households.



(a) Populations private and industry **(b)** Populations only private households

Figure 3.1: Venn Diagrams

3.2 Procedure

The experiment included the installation of the smart meters and the deployment of the web application. It was started in November 2014. The test area was the 'Smart City Villach' in Carinthia. At the same time a survey, has been conducted, to determine the demography of the participants, and to increase their knowledge on smart meters. The elicitation has been accomplished by employees of the energy provider (Kärnten Netz GmbH, in short: KNG). They did a face-to-face survey and reached 203 participants from 530 in total. Normally they met them at their homes. Each household and company in this area was informed about the experiment and the mouse tracking, either during the survey or by means of a letter. Everyone who wanted to participate, had to sign a declaration of consent, which had to be returned to the energy provider. After the declaration of consent reached the KNG, letters were sent to them containing the login information among other clarifications. Then the user's were able to visit the web application whenever they wanted. Each visit was logged and tracked by the KNG. At the end of the project the gathered data was given to the universities for the evaluation.

3.3 Technical Setup

The user's procedure of the experiment has already been explained. Now the procedure for the research team should be mentioned. The responsibilities of the stakeholders, and the timeline is described in detail.

3.3.1 Project timeline

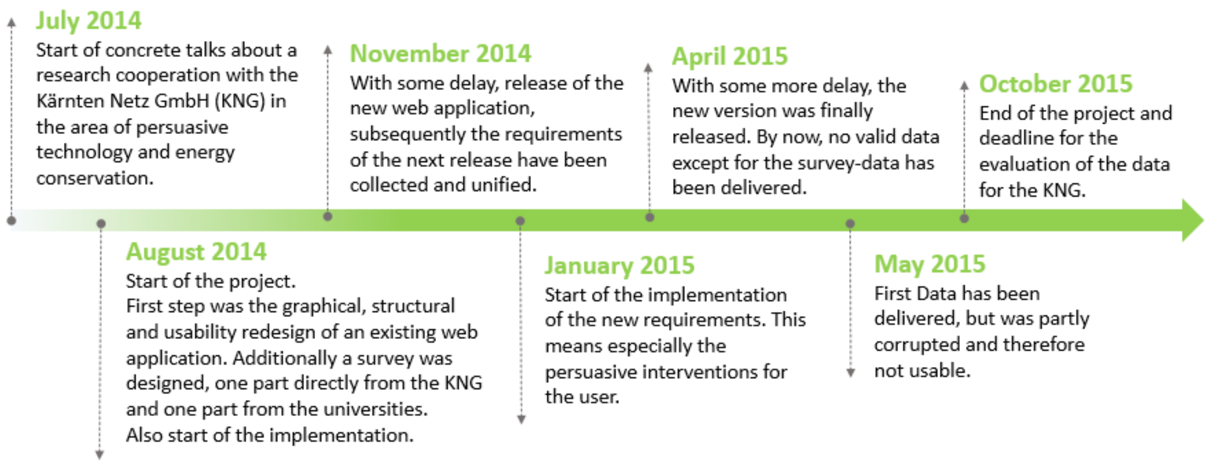


Figure 3.2: Overview of the progress of the experiment

The whole experiment lasted for more than a year from start to the final report. The estimations accounted for 8 months, but the problem was that the development as well as the quality assurance took much longer than assumed. Requirements changed in the middle of the project and interfaces where more difficult to implement than expected. An example of this problem can be seen in the following timeline. In stage two the implementation of the requirements took about one month. It took further two months to finally release it.

Here is the timeline of the experiment:

21.07.2014 - 05.08.2014 cooperation meetings of all stakeholders and start of the project

05.08.2014 - 01.09.2014 requirements engineering for a necessary redesign due to usability issues and specification of the mouse tracking implementation, introduction of a scrum board

01.09.2014 - 20.09.2014 requirements finalization, including MockUp designs made with Balsamiq ®, parallel implementation

01.09.2014 - 13.10.2014 implementation

13.10.2014 - 06.11.2014 conducting the survey

13.10.2014 - 10.11.2014 quality assurance for stage one, bug fixing

10.11.2014 release stage one

11.11.2014 - 15.01.2015 requirements engineering for stage two, specification intervention

15.01.2015 - 04.02.2015 implementation

04.02.2015 - 16.04.2015 quality assurance for stage two, bug fixing

16.04.2015 release stage two

16.04.2015 - 31.08.2015 quality assurance for database export, bug fixing

31.08.2015 - 23.09.2015 explorative analysis

23.09.2015 - 23.10.2015 final evaluation of the results

23.10.2015 submission of the final project report

3.3.2 Sequence of the experiment

The project had security issues due to the real-life, and real-time data processed therein. Thus the access to databases and source codes was restricted for the universities. This is why the study sheds its light only on information and work packages that were accessible, or worked on, by aforementioned universities.

The following is an explanation of the stakeholders and their work packages:

- Energy provider: Project management, back end development, requirements engineering, interface development, customer service, smart meter installation
- External development team: design (especially CICD), implementation front end, interface development
- Universities: design, requirements engineering for interventions and usability, quality assurance and evaluation

3.3.2.1 Work packages

As explained, each stakeholder had several work packages he was responsible for. This work was done by the universities. An explanation of their work packages is as follows:

For the Information System, the conception of the design will be discussed in detail in the next chapter, which also includes the requirements engineering for the usability issues and the specification of the persuasive intervention.

The quality insurance, done by myself, referred to the front end of the web application in stage one. In stage two, as an addition, the back end calculations for the intervention had to be verified. To guarantee adaptability, transparency and controllability scrum, a method of agile software development was used for the interaction between the universities and the development team. This is the reason, why Trello ® [Inc., 2015] was used.

The requirements were added to the system specification file and, if required, adapted in the meetings. Especially for the implementation of the intervention, and for the quality assurance, this was not enough, therefore a scrum board was used.

Scrum is normally used for teams ranging from three to nine people, so it was not practical to give writing access to the energy provider too. To ensure transparency, the energy provider got reading access though. Trello ® can be used as scrum board, because, for each open development issue or bug one can categorize it, and assign it to a person and/or field of activity. Here is one example of an issue during the development process:

The issue for a bug is created and assigned as 'reported'. If a programmer wants to get rid of the bug, he categorizes the issue as 'in progress'. When he finishes the work, it will be categorized as 'completed'. Then the quality management verifies if the bug is finally fixed. If so, it is classified as 'finished'. If not, it is again declared as 'in progress'. For the second quality assurance, a detailed test sheet was produced to standardize the process. In this stage, database access was needed, and therefore the employees of the energy provider assisted in working on the quality assurance.

Finally the evaluation of the results was conducted by the universities. For this task, some tools were developed (all in c# with .NET framework) to preprocess the data, so it was possible to use an evaluation software like SPSS and OGAMA. These will be explained later on. The results of the evaluation will follow in chapter 5.5 and 5.6.

3.4 Variables and Data

The experiment and also the evaluation held a strong explorative character, due to limitations involving an industrial research project. Also, the volume of the data was quite extensive. Therefore, this section explains the origin of the raw data, and afterwards describes the tracking and the consumption data in detail.

3.4.1 Raw data

The data, which is the groundwork for this analysis, has been collected between the beginning of November 2014 and 20.09.2015, by using different methods. The surveys were made as face-to-face interviews. Additionally, on behalf of the KNG, a telephone survey was conducted. This survey was compiled in a way to make potential conclusions about real identities impossible, and therefore the data couldn't be used. All further data records originate from the databases of the energy provider itself, or were exported from the databases of the web application. Next is a detailed list of the raw data with an explanation of the respective content. Also included are the origin, cardinality and the affiliation to the specific population

1. KNG survey: demographic data and questionnaire about Smart Metering, face to face survey. 203 full records from the test area.
2. AAU survey: Questionnaire about the attitude towards renewable energy and competition habits, face to face survey. 61 full records from the test area.
3. User: List of anonymous UserIDs of the participants in the test area, KNG database. 306 full records from the declaration of consent.
4. Consumption data: List of the consumption of all calendar weeks in the test period, KNG database. 306 full records from the declaration of consent.
5. Mousetracking - Overview: Overview of the user sessions in the web application, web portal database, 723 full records.
6. Mousetracking - Tracking data: the recordings of the mouse movements of user sessions, 589 valid records.
7. Mousetracking - Click data: the recordings of the click events within user sessions, 449 valid records.

3.4.2 Tracked data and variables

It has to be mentioned that this project involved real customers, so the possibility for e.g. additional questionnaires was limited, in order not to annoy the utility customers.

Following, is a thorough description of the fundamentals of the data files. The session file contains all recorded sessions from all users of the web application.

It was important to observe, what each single user had seen during his particular session. Those statistics include his rank, or his own profile data. Each user was able to generate more than one user session, this leads to the situation, that it is necessary to monitor all results, to not get any false positive results.

This is the structure of a session log, which was made in the systems background:

- Unique ID of the session
- Start- and end time of the session
- User ID (of course anonymous)
- Profile information of the user in this session (amount of adults and children and square meters)
- Amount of to-dos which where added or created during the session
- Device which was used for the session (pc or mobile device)

- Browser which was used for the session
- Possible feedback of the user
- Relevant ratios for stage 2
    - Current rank of the user
    - Current background color of the rank

Additionally thereafter,the following informations were extracted from the mouse tracking (with OGAMA) or click files (calculated with a self made short c# program) or calculated from the session information itself (calculated with a self made short c# program).

- amount of clicks on the sub sides ('web', 'electricity', 'compare', 'tips', 'to-dos', 'profile' and others like imprint)
- Mouse tracking information for 'web', 'electricity' and 'compare'
    - amount of fixations
    - length of mouse paths
- Consumption information of the users at the time when the user visited the application (5 calendar weeks, starting from two weeks earlier, ranging until two weeks afterwards)
- the completeness of the record: if the user has consumption information for all five weeks or if the user was on vacation (if the consumption dropped by more than 50% compared to the previous week)

3.4.3 Consumption data

In this subsection the focus lies in the consumption change originated from the intervention. Assumptions and premises, that are necessary to analyze the data correctly, will be explained. The importance to precisely specify the assumptions is a mandatory consequence due to the fact that it is a real live experiment, without any controlling factors that can influence the behavior of the participants. To specify the assumptions in this way, the variables, which were consulted for the calculations, will be explained in detail.

3.4.3.1 Premises and Assumptions

It is not useful to analyze the absolute consumption values, because they consist of real live data, due to unknown influences. For example: Each user has a specific household size, but for some users this value is unknown. The same is true for apartment type or square meters. Additionally, each user follows his individual consumption behavior, which is influenced by his personal circumstances. An example for such circumstances is, a pensioner stays longer at home, and therefore spends more electricity than someone who is employed. In another example a younger person normally possesses a higher quantity of electric devices, and uses them more often than older people. For the experiment other influences, like the weather for example, did not matter, because all users resided in the same geographical location (one bigger city block), therefore, all participants should experience similar outer influences. Their impact causes other effects though, as it can be seen in 5.2, the slow but steady decrease of consumption from winter months to summer months. It is assumed, that this decrease of energy consumption due to the change from winter to summer months, distributes evenly among all households.

To avoid false positives results, it was necessary to exclude all incomplete or extraordinary records. This means cases, in which values are missing in the record, because the smart meter was not installed yet or the person just moved in or out. Special cases include vacations or other extraordinary consumption decreases. As a threshold a decrease of more than 50% compared to the previous week was defined.

3.4.3.2 Variables

As already mentioned in the previous subsection, it was not possible to run calculations on the absolute consumption values of the user, so it was necessary to work with 'difference values'. Those are set as the following variables:

- div_prev is the difference between the energy consumption two calendar weeks before the visit, and the energy consumption one week before the visit
- div_cur is the difference between the energy consumption one calendar week before the visit and the energy consumption of the calendar week while the visit
- div_aft is the difference between the energy consumption of the current week and the energy consumption of the calendar week after the visit
- div_aft2 is the difference between the energy consumption of one week after the visit and two calendar week after the visit.

Test auf Normalverteilung

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
div_prev	,268	678	,000	,432	678	,000
div_cur	,362	678	,000	,155	678	,000
div_aft	,309	678	,000	,200	678	,000
div_aft2	,279	678	,000	,293	678	,000

a. Lilliefors Significance Correction

Figure 3.3: Test for normal distribution

All these variables are not normally distributed, as can be seen in graphic 3.3. Due to the fact that in this case the sample had in this case over 200 records the Kolmogorov-Smirnov Test was conducted ([Smirnov, 1944]). Due to this non-parametric statistical tests were used. Even the variables are not normally distributed, some parametric test are stable enough to work with variables which are not normally distributed, if certain conditions are fulfilled. In our case the Q-Q-plot in graphic 3.4 shows, that it is necessary to work with non-parametric tests.

To be able to recognize, which effects and interventions had an impact during which part of the experiment, the following variables were used:

- Duration: is the dwell time of the current session, or more detailed, the time, which a user spent with the web application, measured in seconds. Due to this it is possible to draw conclusions about the efficiency of the intervention.

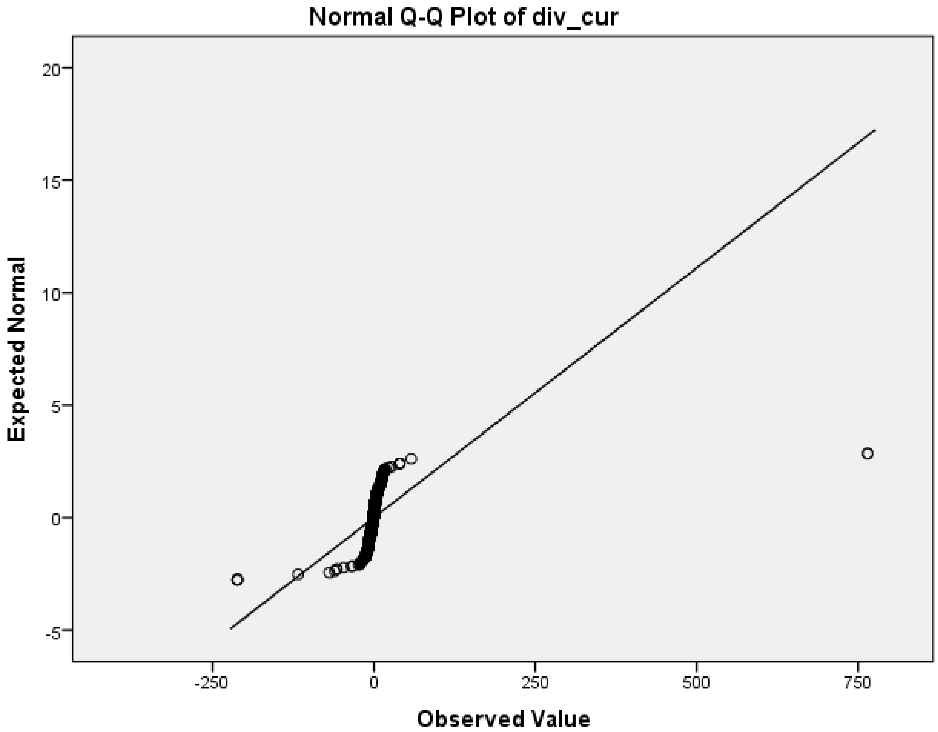


Figure 3.4: Normal Q-Q Plot of div_cur

- Click events: the amount of clicks on a sub site of the application in a specific session. With this, it is possible to identify a correlation between the intense usage of a sub site and the energy consumption.

  Web: the amount of clicks on the sub site web

  Energy: the amount of clicks on the sub site energy

  Compare: the amount of clicks on the sub site compare

- ratios of stage 2: To identify a correlation between the ranking intervention and the energy consumption of a user

  Rank: current, absolute rank of a user

  Color: background color of the rank

- Stage: the stage were the session took place

- Attitude: the user's attitude towards renewable energy

Chapter 4

Design

This chapter explains in detail the design of the Information System for both stages, including the explanation of the background calculations, which were needed for the persuasive intervention in stage two.

4.1 Stage 1 Redesign

To get a more attractive website for a new web application, the 'Kärnten Netz GmbH' has decided to reuse the structure an already existing one, made by a Carinthian company named Symvaro. As can be seen on the following screen shot, they called it 'Energie Genie'.

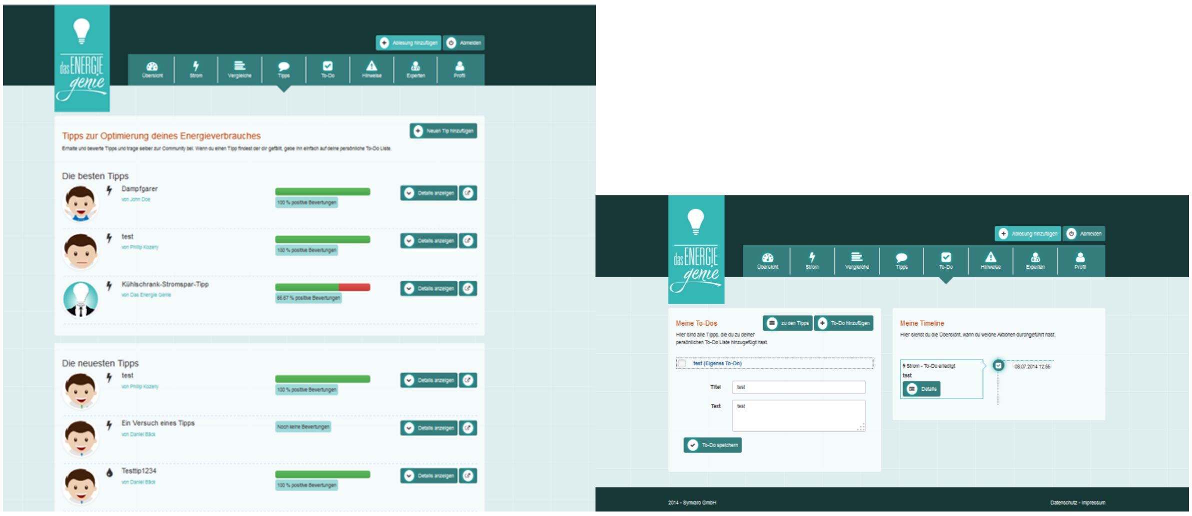
(a) Energie Genie - Dashboard

(b) Energie Genie - Energy - Overview

Figure 4.1: Energy Genie, source: [Symvaro, 2014a]

The idea of the 'Energie Genie' was to support their costumers to save energy with self monitoring as well as with group interaction. 4.1 shows the Dashboard where the users get an overview about their own consumption, to-dos, tips from Experts and so forth.

A sub site shows the consumption-history of the user. This is possible for different periods of time and in different measuring scales like in kilowatt hour or in Euro. The next figures 4.2 display the tips and to-do screen. It should support the user to get rid of energy waste. Users and experts are able to support the community with helpful tips, and the community rates their effectiveness. The user himself can store these tips in his own to-do list. The effectiveness of his own household is also shown in the Energy Overview. It displays the start and the end time of the saved to-do in the households consumption line diagram.



(a) Energy Genie - tips **(b)** Energy Genie - to-dos

Figure 4.2: Energy Genie, source: [Symvaro, 2014a]

There are more functionalities provided by the 'Energie Genie', for example a comparison between the user's energy consumption and the consumption of all other households. Alerts: this particular part of the website was made because not all users have smart meters in there homes, so they can provide the energy consumption manually. The last two sub sites are 'experts' and 'profile'. Experts: where a user gets instant help from an energy expert of the energy provider. Profile: were a user can set up a profile of his household.

Even if the web application has very good intents, for a valid research approach and also for the companies needs, it was necessary to redesign the application. The website had to get rid of three major problems: complexity, missing traceability and missing usability. Of course the website had to be redesigned to correspond with the CICD (Corporate Identity and Corporate Design) of the 'Kärnten Netz GmbH' and the interface too had to be expanded, to integrate the smart meters of the company.

4.1.1 Redesign of the web application

The major goal in this state of the experiment was to ensure that the web application grounds on usability and credibility, which is the base of every persuasive method as already mentioned.

Because of the scope of this project it got divided into two parts. The first part just contains the implementation of the requirements for persuasive methods and the traceability of the user's behavior. The second part was, except for a few bug fixes and design improvements, only the implementation of the persuasive intervention.

Even though the persuasive intervention is added during stage 2, the web application fulfills the requirements to influence the user's behavior already in stage 2. The application in stage one can be labeled as a tool with focus on two principle: reduction and self-monitoring. According to the behavior grid, the web application should start a 'familiar behavior from now on' (blue path). The familiar behavior is assumed, because most methods to save energy are known to the users, but characterized as annoying or stressful for him most of the time. Self-monitoring could therefore be an appropriate way, if the user has a prior attitude to save energy. The redesign, based on the principles for Tools, should lead to a sustainable energy reduction.

4.1.2 User Interface improvements

The following changes were all implemented and completed in stage one, the persuasive intervention will be discussed later.

The first stage of the experiment was the implementation and the redesign of the basic functionalities and should also be an appropriate base for the persuasive invention. These basic functionalities are prescribed by the legislature and by the perception of the grid provider.

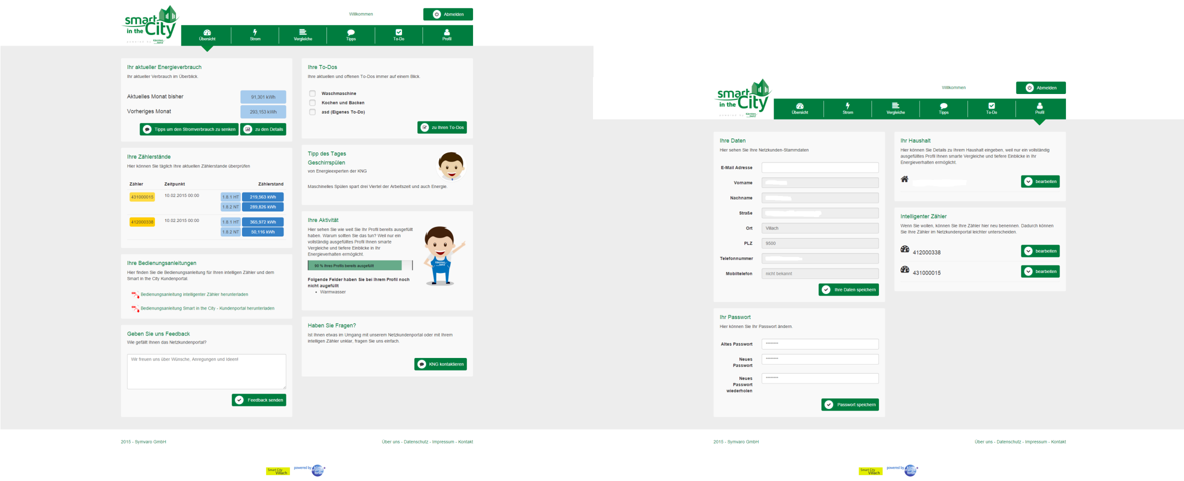
The universities redesigned the web application with their specific know how. Our first step was to reduce the amount of functionality provided at the main view to give the user a faster and easier overview of the website. We decided to get rid of the expert and the alert sub sites and also dropped the social network integration. All interactive design elements like buttons were streamlined and positioned correctly. For example the continue buttons were placed on the bottom right site or specific interaction buttons went to the top right site. Furthermore, the colors of interactive element or design element were unified. Finally the website got the look and feel of the energy provider 'Kärnten Netz GmbH'. From now on the web site was called 'Smart in the City Web application', named after the test project of the energy provider.

The index page of the web application is the so called Dashboard. After the login the user is redirected to his dashboard. The dashboard gives an overview over all functionalities of the web application. It is divided into 8 different areas, each one for a certain feature:

1. electricity: Shows the consumption of the actual and the last month.
2. actual count: Shows the actual meter reading.
3. manual: Offers a download of the manual for the smart meter and the web application as PDF.
4. feedback: Contact form to give direct feedback to the KNG
5. tip of the day: Shows the tip of the day, written by the experts of the 'Kärnten Netz GmbH'

6. activities: Shows how much of the profile is already filled out

7. contact: Leads the user to the contact form of the KNG

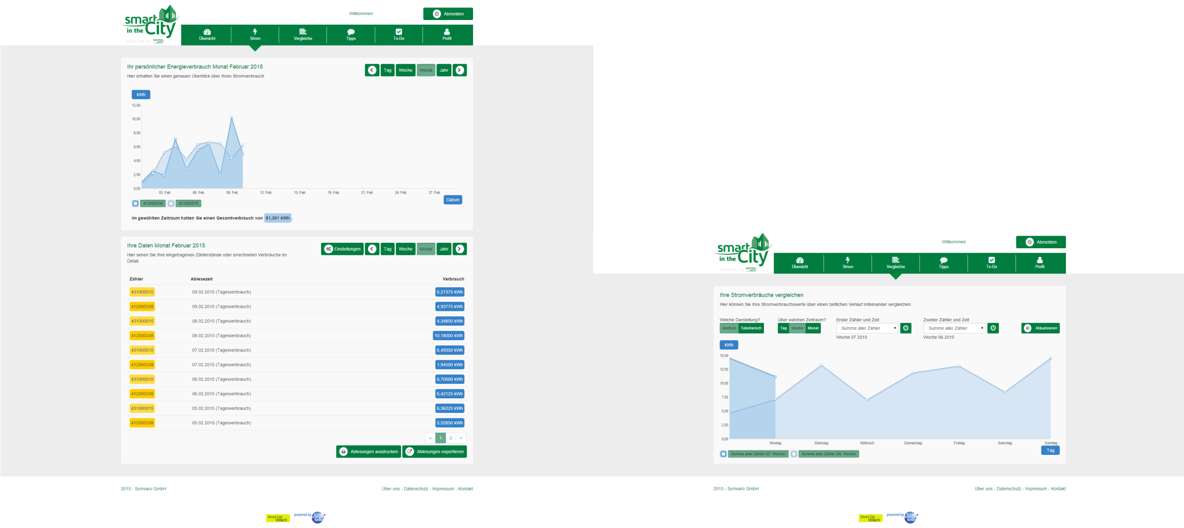


(a) Sub site Dashboard **(b)** Sub site Profile

Figure 4.3: Start- and profile sub sites, source: [Symvaro, 2014b]

Figure 4.3 shows also the profile sub site, where the user is able to look at or change his profile settings, email address or password. Additionally, all smart meters, which are linked to the customer, are displayed.

Two sub sites revolved around the own energy consumption and a comparison thereof. These are called ’electricity’ and ’compare’, as it can be seen in figure 4.4. In electricity mode, a graph representing the users consumption will be shown in the upper area of the page. Therefore, the customer has several choices between several aggregates (hour, day, week) for different points in time. Also a view of a single day by quarter hours is possible. These informations can be viewed for each connected smart meter the user owns. The second part of the sub site has the same functionality, here the data will be shown in tabular form. Additionally, the user has the opportunity to export the data or to print the view directly.

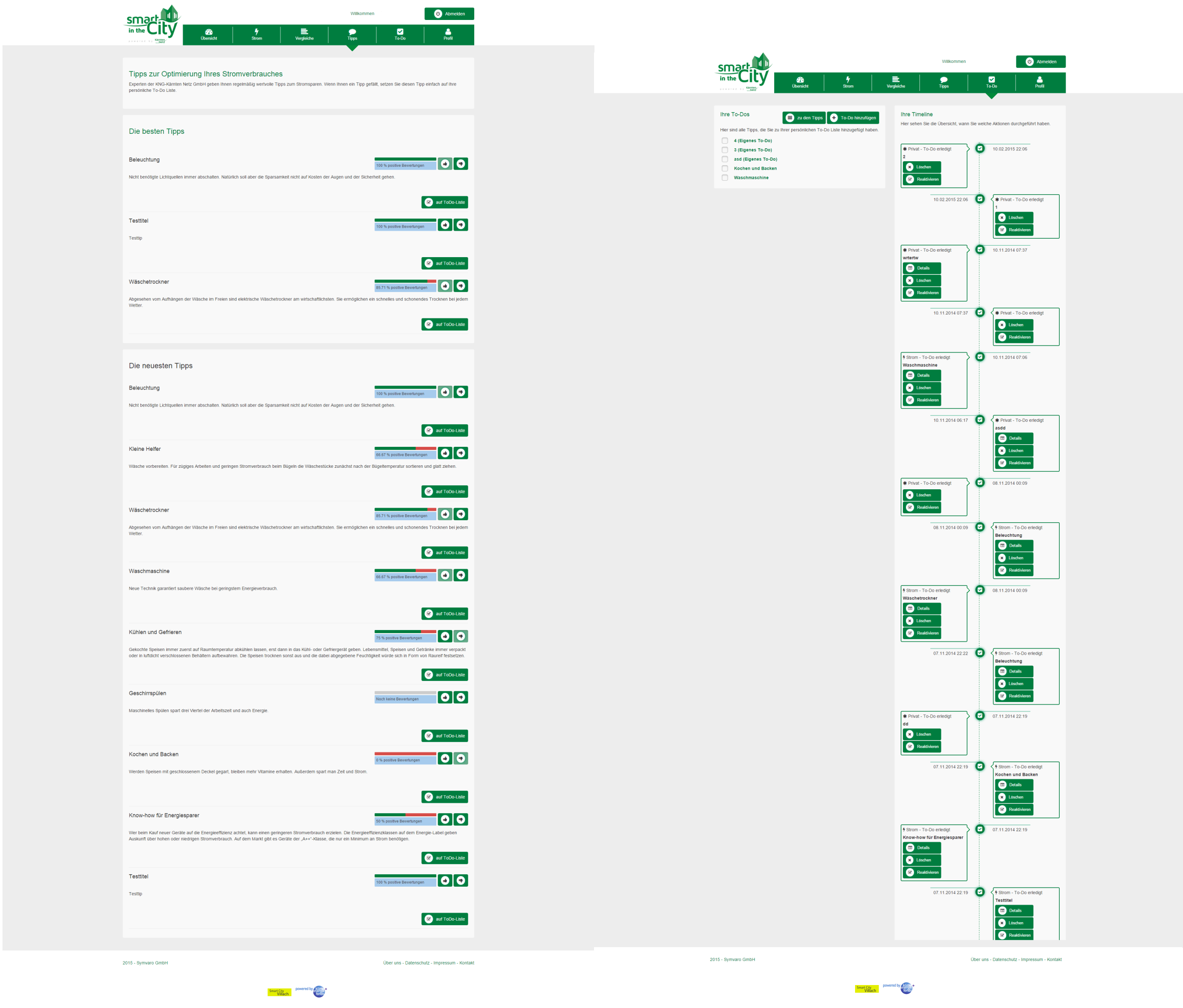


(a) Sub site electricity **(b)** Sub site compare

Figure 4.4: Consumption overview, source: [Symvaro, 2014b]

’Compare’ is dedicated to the comparison of the household’s own consumption data. The user has the possibility to compare the data view in graphical or in tabular form, for different days, weeks or months and for different meters.

Complementary to the necessary content, the web application also serves two additional features, ’tips’ and ’to-dos’ 4.5. The ’tips’-feature provides helpful energy saving tips from the experts of the energy provider ’Kärnten Netz GmbH’. The user can evaluate them and also add them to his own ’to-dos’. These tips are also grouped in newest and best ones. With the aid of ’to-dos’ users are able to save their own goals and ideas regarding energy saving, or to follow one of the tips of the energy provider. To get an overview of the already implemented tips, there is also a chronic where all finished to-dos are listed.



(a) Sub site tips **(b)** Sub site to-dos

Figure 4.5: Features, source: [Symvaro, 2014b]

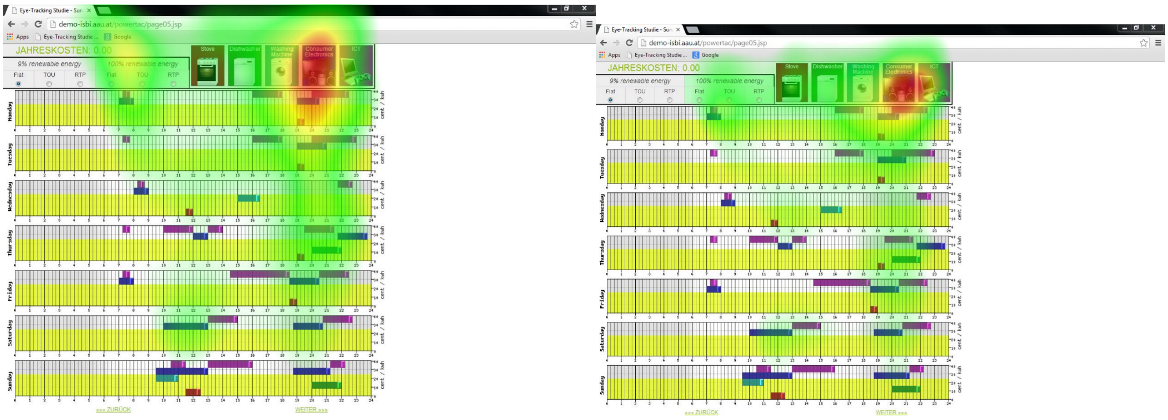
4.2 Mouse tracking

To be able to track the behavior of real customers of the 'Kärnten Netz GmbH' in their natural environment, and due to the amount of users who are participating, mouse tracking seems to be the best method. To evaluate the accuracy of mouse-tracking beyond literature sources, even a prestudy was conducted.

The technology of 'mouse tracking' was the backbone of the experiment. Mouse or cursor tracking refers to the recording of mouse movements during human computer interactions. It is commonly used to increase the usability on web applications. One of the first utilization was done by [Spivey, Grosjean & Knoblich, 2005], who tried to understand real-time processing in the context of spoken word recognition with cursor tracking technology.

In a previous laboratory experiment conducted by the university eye tracking was used [Aigner, Zanker & Rook, 2014]. Eye tracking records the position, the user is looking at. This is of course a much more precise method, but in exchange it requires expensive equipment and most of the time also a supervisor. The disadvantages of including a supervisor is, that the test results could be influenced or distorted. In a real life experiment, other than laboratory experiments it is not possible to apply eye tracking technology yet. Therefore mouse tracking is a cheap and easy surrogating method, with an accuracy up to 88% [Chen, Anderson & Sohn, 2001].

Besides the eye tracking records also the mouse movements were recorded in this previous experiment. This is the reason why it was possible to test the accuracy of the method on a small group. Here is an explanation of the experiment: it was supervised and the participants had an application on a computer where they got some information about energy tariffs and some slides with instructions and explanations. Then they were able to reconstruct their own power consumption situation on a tool and afterwards compare the different tariffs. On slides where no interaction was needed, the accuracy of mouse tracking compared to the eye tracking was not very high. On the tool though the opposite was the case, as can be seen in the following figures.



(a) Attention map of a tool with eye tracking records **(b)** Attention map of a tool with mouse tracking records

Figure 4.6: Attention maps tracking possibilities, source: [Aigner, Zanker & Rook, 2014]

Mouse tracking means that the application records the mouses' x-, and y- coordinates. Mouse clicks are recorded on their own as 'click events'. In this case JavaScript was used on the client side of the web application to record whenever the mouse gets a new position. After a few milliseconds the summary of the records are sent to the servers of the company. The coordinates combined with the time stamp of the user's mouse movements or clicks allows a reproduction of every single action the user made on the web application. On the Server-side the data was transformed to csv-files. Every session had it's own tracking file with mouse coordinates including time stamp and sub site of the web application for each record, as well as a click file with the same information. It is to mention, that because of the evaluation software, the data had to be post processed. In JavaScript it proved to be difficult to record the mouse position every 20 milliseconds when it was not moving, but it was easy to register any mouse movements. For the evaluation software OGAMA it was necessary though, to get the mouse position every 20 milliseconds, to calculate fixation points and heat maps. To achieve this task, the following post processing was done: If the mouse position does not changed for more than 20 milliseconds, the last record should be duplicated with the previous time stamp plus 20 milliseconds. This implementation was made by the third party company.

To implement this measurement method, also to reconstruct the user's behavior, the application has to fulfill certain requirements. This is the reason why a responsive design of the web site was not an option. All graphical areas were required to remain in their specific position. Dynamic growth is only allowed on the to-do sub site, such that the functionality and the design is not broken.

As already mentioned the evaluation software was OGAMA ([Voßkühler *et al.*, 2008]). OGAMA is an open-source project for recording and analyzing eye- and mouse tracking data, written in c# and .NET. For this study the file importing software part had to be adapted to import more than one external raw data file. This software was used especially for calculating the attention maps (as explained later on), and also for fixations and other descriptive statistic ratios.

4.3 Stage 2 - Persuasive Intervention

Finally in stage 2 the persuasive intervention, the so called ranking, was developed and implemented.

The persuasive intervention upgrades the web application from a Tool to a Medium, by additionally motivating the user with his personal ranking. Due to the setup of the experiment, the ranking should now reinforce the former behavior (purple path). This is why the intervention will have combine the Suggestion and Condition principles [Ferebee, 2010]. If this intervention does in fact have an impact on the users, it should increase their saving potential even more in comparison to stage one.

The reason to wait for the final requirements for the ranking, was, to get additional information about the user who would use the web application. The foundation was a demographic survey from the energy provider, where user provided personal data information about themselves and their households, such as amount of people who lived in their apartment, or which type of heater they use.

The intervention was based on two main ideas: First, we had to design a game-like information element, to give the user a reason to log into the web application at least once a week. The second idea was, to make the website more attractive via a competitive group-mode. Therefore the ranking is a functionality that should lead the user to a positive behavior change, concerning his energy consumption in response to the social and personal aspects. This methodology in the human-machine-communication is commonly known as Persuasive Technology. The intention of the ranking is, that a user is able to compare himself with his direct neighborhood, or to reach a personal high score, which therefore also includes gamification aspects.

4.3.1 Ranking

For the comparison in the direct environment, the participants were grouped by similar demographics and consumption preconditions, because comparing between a one-person-household with teleheating, and a five-headed family with electric heating, will obviously lead to wrong conclusions. Therefore the participants should see that they were matched with similar households.

More detailed: the comparable households are households with the same amount of residents as well as same heating and water-heating systems. All participants live in the same test-area so they have the same weather-conditions. We had different groups of comparable households for our experiments. Based on the survey of the energy provider we identified four groups where the cardinality was sufficient:

- 1-2 residents, non-electric water-heater, non-electric heater
- 1-2 residents, electric water-heater, non-electric heater
- 3+ residents, non-electric water-heater, non electric heater
- 3+ residents, electric water-heater, non electric heater

The outcome was a new area in the ’compare’ sub site, where the user is able to compare himself with his direct and comparable neighbors, and display this with a rank. The ranking is calculated by last week's consumption in the households. Additionally, they also get a related area where they are able to compare themselves with their own last week and the average of all households in their specific area.

Other households with electric heater for example, are not numerous enough to form a separate group, so they don't get a rank displayed. They just get a comparison to themselves. Also to mention is, that only private household get this view. Companies were not part of this experiment.

4.3.2 Rank

Every day, after the insertion of the data into the system, the aggregates (hours, days) are computed on the basis of all meters in the specific household. The calculation of the rank is executed once a week for the prospect and is displayed to the user for the last week. The group affiliation is based on the profile information to household size, heater and water heating condition at the time of the calculation. This means, that changes in the profile information during the week, which were changed by the participant, will be ignored. Changes in the household size from one to two or vice versa, or between 3 or more people, stay without any impact on the group affiliation. If there would be a change in the profile which would lead to a different group membership, the participant wouldn't get a value for the previous week as a result. All previous calculations will remain for all other households. The comparison of the key ratios doesn't change the group affiliation. After the calculation of the group membership, the allocation of the rank in a group will be calculated by following rules:

- Sort the group ascending by their overall consumption from last calendar week
- the calculated index is the rank in the particular group
- the maximum of the index is equivalent to the group size
- if the group size is less than four, no rank will be displayed to its members

4.3.3 Color

The background color of the rank and the key ratios is relative to the improvement or the worsening of the energy consumption of the household. Due to the color, the user is able to get a fast overview with the aid of the 'traffic light consumption labeling system' to recognize, if their own consumption behavior increases (green), stays the same (light green), gets a bit worse (yellow), or gets worse (red). Because there are not any empirical values, it could be, that for a real live system the values have to be adjusted.

The rank of a household, as well as the key ratios for the same week, are highlighted by the same color. The detailed explanation of the color scheme follows these rules:

- dark-green: Shows an energy reduction of at least 5% in comparison to the last week.
- light-green: Shows that the energy consumption nearly stays the same. Light green is also used in the event of increased energy consumption due to changed weather conditions if the user stays in the same rank compared to the other households.

- yellow: Shows an increase of the energy usage by at least 5% AND an increase in comparison to the neighbors. So he has to drop by one rank.

- red: Shows a high increase of energy consumption by at least 10% AND an increase in comparison to the neighbors. So he has to drop by one rank.

4.3.4 Implementation

On the dashboard 4.7 a new area was added, which gives a short overview of the user's competitive statistics: rank of the last week, consumption per square meter and residents, also for the last week. We use 'last week' because we only focus on full calendar weeks. A button leads you directly to the details. If a user didn't fulfill the requirements to be in a group, a question mark will be displayed on the rank area of the dashboard. If a participant didn't fill out his households profile with the minimum requirements (household size, heating type, water heating type) a sad meme is displayed, either with the message, that we are not able to calculate a rank, or with the request, to finish the profile. If the user does, he gets a message that a rank will be available for the next calendar week.

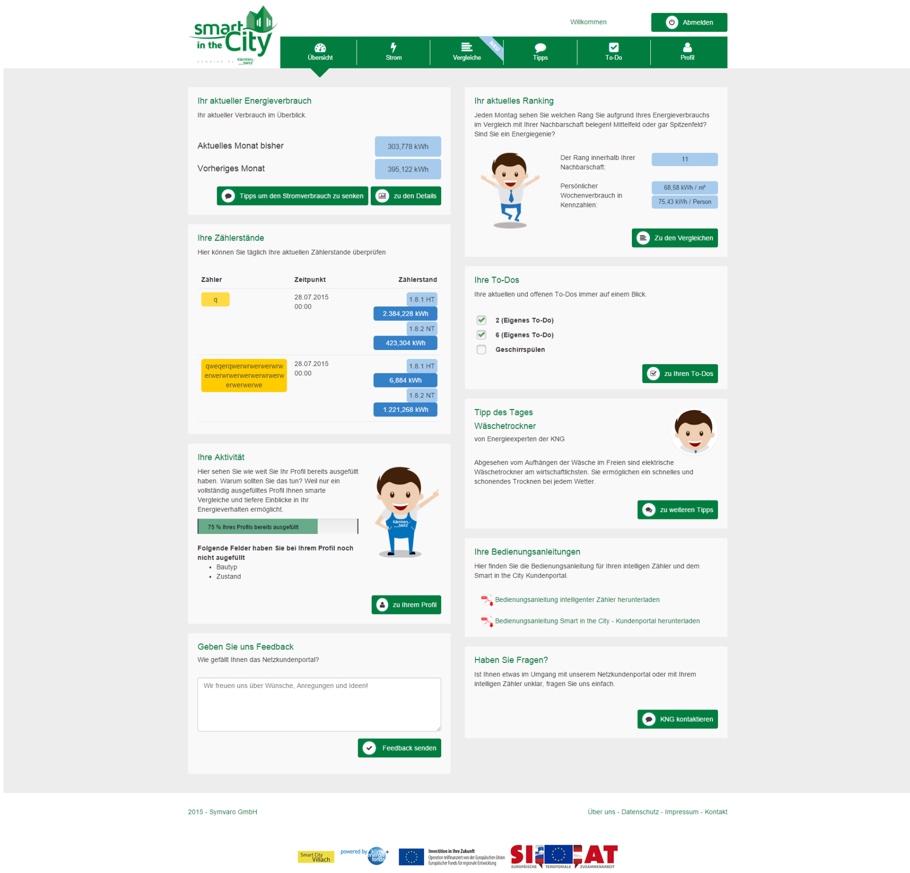


Figure 4.7: Smart in the City - Ranking Dashboard, source: [Symvaro, 2014b]

The second figure showed in 4.8 is the detailed comparison for households, which have comparable homes. The left area shows the comparison among the comparable households. In the center of the area, the rank is displayed. Below that, the user gets the information on how much energy the participant has to reduce, to achieve the next rank. The last line contains the rank of the previous week. The question-mark button in the upper right corner shows an explanation of the group and the calculation of the rank and the key ratios. All ratios are highlighted with one of four colors: dark-green, light-green, yellow or red. It supports the user in getting an easy understanding of his own consumption behavior.

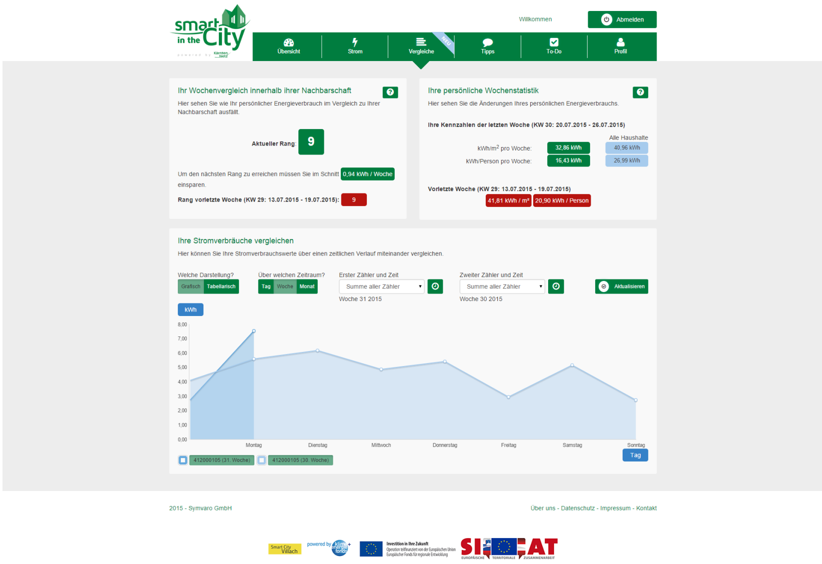


Figure 4.8: Smart in the City - Ranking Compare, source: [Symvaro, 2014b]

On the left area the self-comparison is positioned. The colors and the question-mark button have the same functionality. The user gets an overview of his own ratios: consumption per square meter and consumption per residents, for the previous week, displayed in the center, and for the week before, in the last line. In the center next to the ratios, are located the ratios for all households in the whole test area - of course without the industry participants.

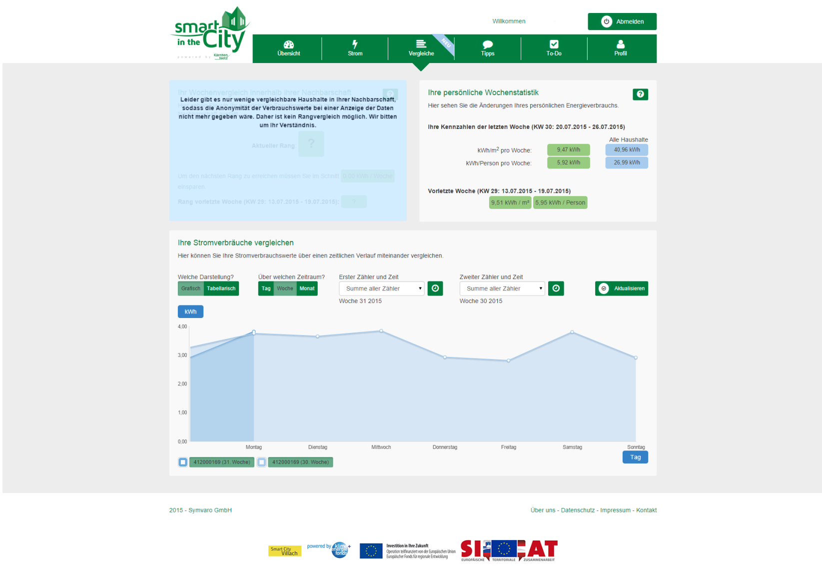


Figure 4.9: Smart in the City - Compare including ranking, source: [Symvaro, 2014b]

If a household is not part of a group, because there are less than four comparable households, the left area will be hidden completely. The background color now just depends on one's own consumption behavior changes, because no rank will be calculated.

Chapter 5

Analysis

This chapter shows the findings in detail. Due to the numerous analyses, it is divided into three parts: population-, behavior- and consumption analysis. 'Population' deals with the descriptive evaluation of the parent population, and examines the differences between different populations in this work. 'Behavior' shows the behavior of the users in both stages, and highlights, which of the sub sites were among the most popular. Finally, 'consumption' shows the evaluation of the hypotheses which were defined in section 2.4.

5.1 Analysis of the population

This chapter lines out the general demographic data of the underlying random sample. Furthermore, the type and the amount of the different data acquisition will be discussed and later be analyzed.

5.1.1 Parent population and web application usage

This section gives a detailed look at the demographics of the survey participants in general, compared to the users of the web application who visited it at least once.

5.1.1.1 Gender

From a total of 194 private household survey participants, 121 (62,4%) were female, and 73 (37,6%) were male. An interesting fact is, that in the portal users population the half of the users stated to be male.

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	73	37,6	37,6	37,6
	1	121	62,4	62,4	100,0
	Total	194	100,0	100,0	

(a) Gender of private population

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	29	49,2	49,2	49,2
	1	30	50,8	50,8	100,0
	Total	59	100,0	100,0	

(b) Gender of private portal user

Figure 5.1: Gender

5.1.1.2 Age

The parent population contains people of all ages. The users are grouped into the following clusters: 18 to 25-year-old are 12,4 %, 26 to 35 year-old 25,8%, 36 to 45 year-old 19,6%, 46-55 year-old 13,9%, 56-65 year-old 18,6% and over 65 year-old are 9,8%.

Age

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	24	12,4	12,4	12,4
	1	50	25,8	25,8	38,1
	2	38	19,6	19,6	57,7
	3	27	13,9	13,9	71,6
	4	36	18,6	18,6	90,2
	5	19	9,8	9,8	100,0
	Total	194	100,0	100,0	

(a) Age of private population

Age

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	8	13,6	13,6	13,6
	1	21	35,6	35,6	49,2
	2	11	18,6	18,6	67,8
	3	7	11,9	11,9	79,7
	4	8	13,6	13,6	93,2
	5	4	6,8	6,8	100,0
	Total	59	100,0	100,0	

(b) Age of private portal user

Figure 5.2: Age

5.1.1.3 Education

An important indicator, if a participant uses the web application at least once, was the level of education. The following rule basically applies: the greater the education level, the more likely the user will use the web portal. In our case all levels of education (the highest educational attainment), were represented: elementary 1%, main school 6,2%, apprenticeship 36,1%, secondary school 11,9 %, high school 21,6 % and University or college 11,9%.

Education

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	2	1,0	1,0	1,0
	1	12	6,2	6,2	7,2
	2	70	36,1	36,1	43,3
	3	45	23,2	23,2	66,5
	4	42	21,6	21,6	88,1
	5	23	11,9	11,9	100,0
	Total	194	100,0	100,0	

(a) Education of private population

Education

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	1	1,7	1,7	1,7
	2	18	30,5	30,5	32,2
	3	16	27,1	27,1	59,3
	4	14	23,7	23,7	83,1
	5	10	16,9	16,9	100,0
	Total	59	100,0	100,0	

(b) Education of private portal user

Figure 5.3: Education

5.1.1.4 Technical versatileness

The vast majority of the parent population claim to be technically experienced to deal with technology/computers or better (68%). Only 7.2% report themselves as not skilled at all.

Skill

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	14	7,2	7,2	7,2
	2	48	24,7	24,7	32,0
	3	79	40,7	40,7	72,7
	4	53	27,3	27,3	100,0
	Total	194	100,0	100,0	

(a) Technical versatileness of private population

Skill

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	4	6,8	6,8	6,8
	2	10	16,9	16,9	23,7
	3	21	35,6	35,6	59,3
	4	24	40,7	40,7	100,0
	Total	59	100,0	100,0	

(b) Technical versatileness of private portal user

Figure 5.4: Technical versatileness

5.1.1.5 Size of the households

Concerning the size of the households, there is no difference between users which use the web application and those who do not. As the following figure shows, the ratio remains stable: one-person households 38,7%/32,2%, two-person households 34,0%/44,1%, three-person households 13,9%/10,2%, four-person households 9,3%/11,9% and five or more-person household 4,1%/1,7%.

Householdsize

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	75	38,7	38,7	38,7
	2	66	34,0	34,0	72,7
	3	27	13,9	13,9	86,6
	4	18	9,3	9,3	95,9
	5	8	4,1	4,1	100,0
	Total	194	100,0	100,0	

(a) Householdsize of private population

Householdsize

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	19	32,2	32,2	32,2
	2	26	44,1	44,1	76,3
	3	6	10,2	10,2	86,4
	4	7	11,9	11,9	98,3
	5	1	1,7	1,7	100,0
	Total	59	100,0	100,0	

(b) Householdsize of private portal user

Figure 5.5: Household size

5.1.2 Summary and Significance

To reflect the impact of such differences between the participating households, which did or did not use the web application, the Chi-Squared Tests were applied to the groups. The Chi-Squared statistical test is appropriate for ordinal or nominal records, to find significant differences between certain groups [Pearson, 1900]. The following hypotheses will be checked:

1. Men used the website more often than women.
2. The younger the person, the sooner he visited the web application.
3. The better the education level of a user, the sooner he used the web application in comparison to the parent population.
4. The better the skill level of a person, the sooner he would use the web portal in comparison to the parent population.
5. The size of the household a person lives in, causes a difference in their intention to use the web application.

The first three hypotheses have been confirmed, the last two didn't show significant differences between the groups. In the following the exact evaluation results are presented:

It could be shown that the use of the web application differs significantly regarding the different genders (p=0,048). On the basis of the cardinality of the sample (>60) the Chi-Squared test has been conducted.

It is necessary to emphasize this result because of the nature of the survey. For each household only one person was interviewed. This must not be the same which also used the web application in the end. Out of 59 households which participated in the survey and used the web site, 19 were single person households, 11 men and 8 women, which supports also our result.

Due to the fact that the variable 'age' has an ordinal scale level, it is possible to work with the Mantel-Haenszel-Test [Mantel, 1963]. With this statistical test it can be shown that there exists a linear correlation between 'age' and the usage of the website (p=0,47).

The characteristics of the variable 'education' are the same as the characteristics for the variable 'age', therefore the same statistical test could be used. Here too exists a statistic significant linear correlation (p=.049) for the variable 'education'.

Both, technical versatility (p=.090) and household size (p=.507) showed no significant correlation.

5.2 Consumption profile

In this section the main part is about the consumption behavior of all participants in the test area. As was already mentioned, the parent population for this analysis had a cardinality of 306 electricity consumers, who gave their consent to the experiment. 256 of them were private households.

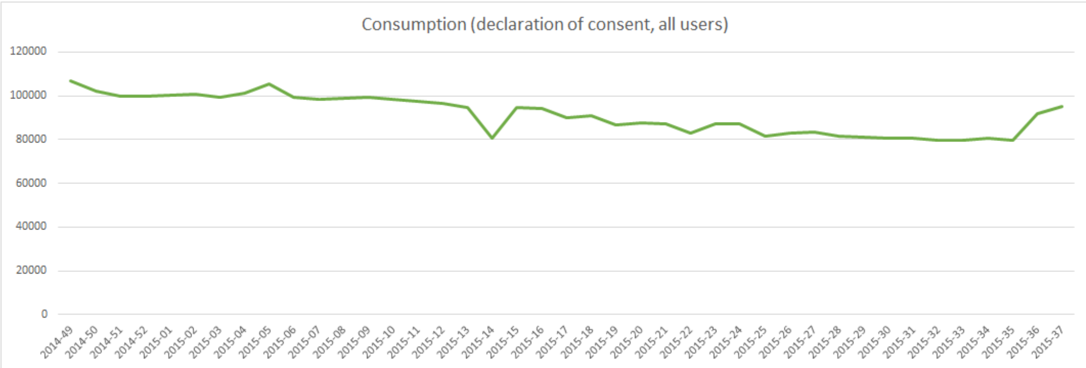


Figure 5.6: Consumption of the population 'declaration of consent'

Firstly, it is necessary to view the total energy consumption in the test area, with and without the industry. Among the 306 electricity consumers, there were 50 companies from small to middle-size, who consumed the majority of the energy. For example: The total energy consumption in the calendar week 2014-52 was 99785 kWh, but the 256 private households consumed only 14972 kWh in total.

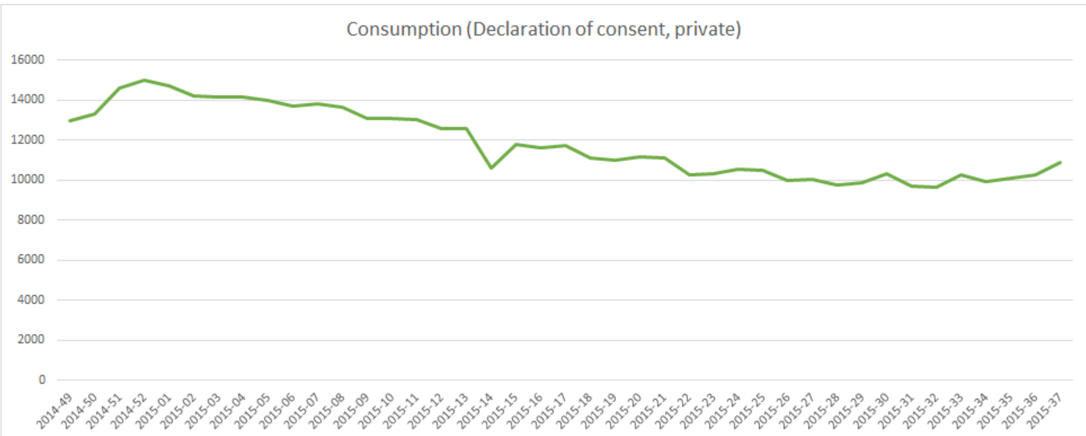


Figure 5.7: Consumption of the private population 'declaration of consent'

Concerning the time line of the consumption, it is firstly necessary to mention that in all figures in this section the first four weeks are missing, as meanwhile the smart meters were installed. This happened from calendar week 2014-22 to 2014-49. Moreover, the first week of each user is also missing because the consumption data could be incomplete. Due to the ranking intervention, only full calendar weeks would be considered.

The energy consumption normally drops from winter to summer. Especially Christmas holidays and New Year led to an increasing energy consumption (calendar week 2014-52). In contrast, the semester break in week 2015-09 led to a small decrease as opposed to the Easter

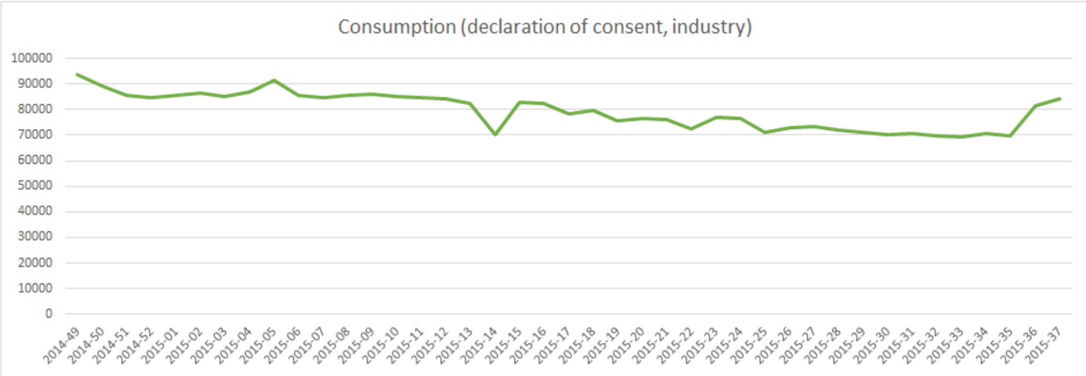


Figure 5.8: Consumption of the industry population 'declaration of consent'

vacation in calendar week 2015-15. Considering the industry in the same time span, the data shows that every time before the start of the vacation the industry needs slightly more energy.

5.3 Web application usage

The following figures show the hits on the web application over the whole test period. Figure 5.9 illustrates all hits in absolute numbers per calendar week. It is crucial to mention that mouse tracking on mobile devices was not possible, as a regular cursor does not exist for these. For standard desktop pc's there is a cursor which can be tracked even if no click event occurs. On a mobile device, the cursors position only becomes apparent if a click event happens. In total, 471 valid click records and 554 valid mouse tracking files remain.

Only 6 out of 50 companies which signed a declaration of consent used the web application with 10 hits in total over the whole experiment period.

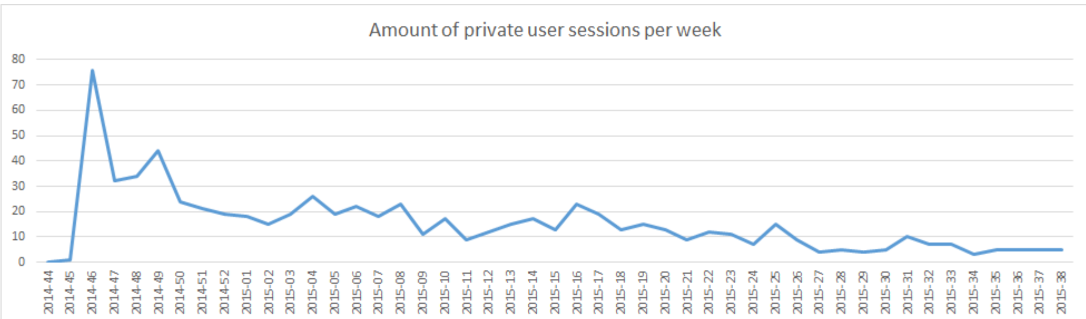


Figure 5.9: Hits of the population 'declaration of consent'

The following figure shows the distribution of the hits for private households for each calendar week. The logging information for the web application was able to output from week 2014-46. Not every user got their information at the start of the experiment. This is also an explanation for the peak in week 2014-49. Subsequently the hits decreased noticeably. The next increase of hits could be seen in week 2015-09, which was also the week of the semester break in Carinthia. Afterwards, the curve drops again and slightly increases at the Start of stage 2 from calendar week 2015-16. At the end of the experiment, the statistical records showed another drop of the hits followed by a phase of stagnation.

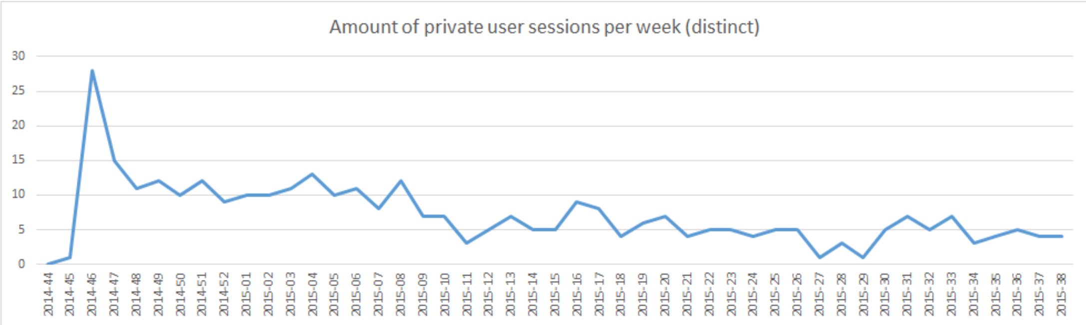


Figure 5.10: Hits of the population 'declaration of consent' distinct for each week

The next figure 5.10 does not count the absolute numbers of hits during the experiment each week. Instead one household could be counted once a week. The first big difference between the first and this figure is that additional emissions did not raise enough interest to increase the hits for the distinct households per week. Additionally, the interest in the web application increased during the holidays more clearly than expected, but dropped even more afterwards. In addition, the course curve for stage 2 is smoother and also showed a small increase at the end of the experiment.

5.4 Mobile Usage

About 26,0% of all households accessed the web application at least once with a mobile device. In total, 119 sessions were mobile hits. The usage of mobile devices decreased in stage 2 because the application did not have a responsive design, due to mouse tracking. The size of the application was static with a width of 1920 px and a height of up to 5400 px.

5.5 Analysis of the user behavior

This chapter describes the results of the experiment in detail for the attitude towards renewable energy and the behavior on the website.

5.5.1 Attitude towards renewable energy

The reason or the motivation why a user wants to use the web application is a major factor for the design of a web portal. With this information it is possible to design the website more attractively for its users. One of these motivating factors was collected with the SurveyAAU. It was the attitude towards renewable energy, also called attitude [Bang *et al.*, 2000]. The value attitude was calculated from six questions. The participants of the surveys responded to these questions by the use of a Likert scale, which went from 'do not agree at all' to 'totally agree with' the assertion.

1. Using renewable energy does NOT make any difference to me.
2. Whether the energy used in my household is renewable is of no concern to me.
3. Using renewable energy is not worth the price I would have to pay.
4. The fact that my household uses renewable energy would make me feel better about myself.
5. The possibility of renewable energy being used in my household means a lot to me.
6. Concern about using renewable energy influences my decisions about energy consumption.

The hypothesis was, that users with a high attitude value, which means the users who had a connection to renewable energy, also used the web application more often. This hypothesis had to be rejected (p=.069). Due to this result and the small sample size, the only statement, that can be made, that there is a slight tendency of correlation between attitude and usage of the web application. For more in depth analysis, another study should be conducted.

Correlations

			Duration	Attitude
Kendall's tau_b	Duration	Correlation Coefficient	1,000	,196*
		Sig. (1-tailed)	.	,039
		N	306	51
	Attitude	Correlation Coefficient	,196*	1,000
		Sig. (1-tailed)	,039	.
		N	51	51

*. Correlation is significant at the 0.05 level (1-tailed).

Figure 5.11: Correlation for attitude and duration

However the value 'attitude' had a significant influence on the average duration a user spends on the web application. This was measured with the variable 'duration' (p=.039) and can be seen in scatter plot 5.12.

For the calculations, a correlation analysis (Kendall' Tau [Kendall, 1938]) was completed, because the variable 'duration' was not distributed normally. This method is also stable against outliers. In this particular case it is possible to assume a unilateral significance, because tendencies in these directions are already known to exist from a laboratory experiment. An additional problem was, the small sample size, because only 20 users participated in the SurveyAAU and also visited the web application. For a causative relation it may be expected that 'attitude' relates to 'duration', because the survey took place before the installation of the web application.

In conclusion, it can be assumed that the attitude of a user had a direct influence on their behavior on the web portal.

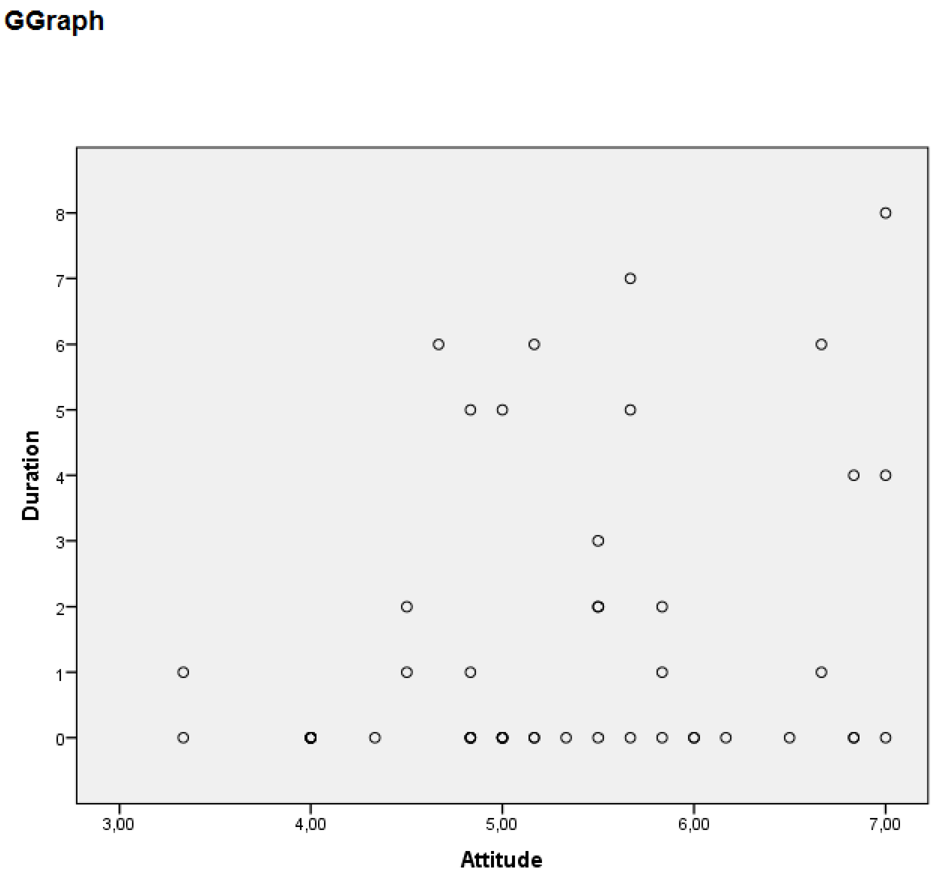
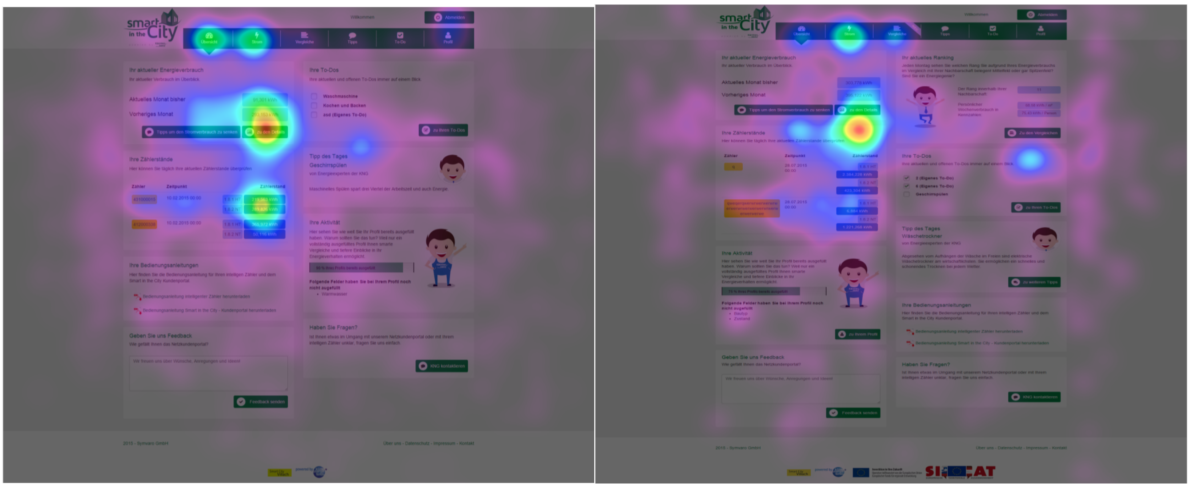


Figure 5.12: Scatter plot for attitude and duration

5.5.2 Usage of the sub site 'web'

The sub site 'web' directly follows after the login screen, and therefore will be accessed at least once by every user. This sub site was not only mandatory, it was also actively used by the participants of the experiment. Of all 723 sessions, only 17 did not record any activity. The following figure 5.13 shows the typical usage from all visitors on this sub site.



(a) Sub site 'web' stage 1 **(b)** Sub site 'web' stage 2

Figure 5.13: Attention map for sub site 'web'

Nearly all users showed a fixation with the upper left block and with the area which shows the consumption values of the users. What also seemed to be important for users was the tip of the day, as well as the meter reading. 87,4% of the sessions contained between one and five actions on this sub site.

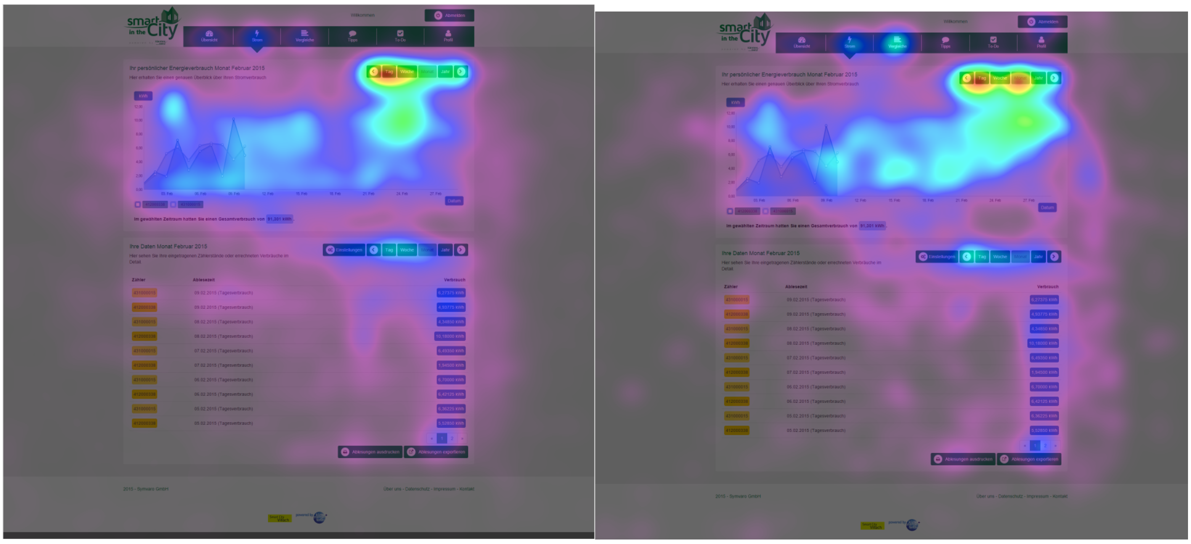
The displayed graphics are so called 'attention maps' (visualized in form of a heat map), these are, maps of the web sites, which are examined. They show, in which zones the user focuses his interest and attention are at their highest. The basis of calculations for the evaluation are the tracking files of all user sessions of either the first or the second stage in the experiment, where mouse tracking files were available. The heat maps are calculated with a software named OGAMA, as already explained before. The colors represent the frequencies or the strength of the attention on an area through a rainbow color pattern: violet corresponds to a scarcely visited or read area, while red shows a highly frequented area.

The user's focus concentrated noticeably on the consumption overview. The difference between the stage one and two is, that the fixations are divided between the consumption overview and the ranking overview. This could not only be recognized in the attention areas on the dashboard, but also in the header, where the comparison sub site got more attention from the users than before.

5.5.3 Usage of the sub sites 'electricity' and 'compare'

Besides the dashboard, 'electricity' and 'compare' were among the most accessed sites of the web application and contained the areas, which had the most intense activities. This can be concluded from the amount of fixations: for 'electricity' there is a median of 36.43 with a standard deviation of +/- 44.178 and for 'compare' the median amounts to 27.36 with a standard deviation of +/- 35.889. For comparison, the value of the median on the dashboard was 9.62 with a standard deviation of +/- 12.067.

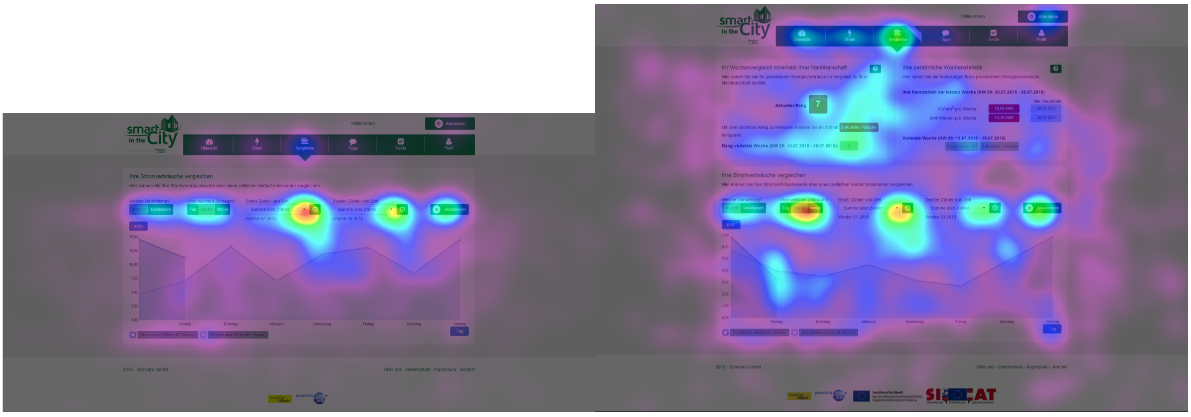
The path length's figure, which is the actual way that the mouse travels onto the website, amounts to a very high average of 9387.1013px with +/- 10999.0508px for 'electricity' and 6741.1789px with +/-8185.1697px for 'compare'. It has to be mentioned that against all expectations, the electricity illustration was obviously more popular than the comparison presentation.



(a) Sub site 'electricity' stage 1 **(b)** Sub site 'electricity' stage 2

Figure 5.14: Attention map for sub site 'electricity'

In the following, the individual stages of the experiment are described: For the 'electricity' sub site, it is important to consider that there are no differences between the two stages in the design. However, in the usage thereof, some variations could be observed. Overall it could be said that the graphic illustration of the consumption was much more popular than the tabular one. During phase one, the day view was very popular, whereas in phase two the calendar view became a favorite. These phenomena could be a consequence of the ranking, because the ranking intervention always referred to a specific full calendar week. The interest on the tabular consumption view also increased in stage two. It became clear from the header that, in stage two, the users often switched between the electricity and the comparison sub site. This was not the case in stage one.



(a) Sub site ’compare’ stage 1 **(b)** Sub site ’compare’ stage 2

Figure 5.15: Attention map for sub site ’compare’

The comparison site was changed in phase two. It was extended by the ranking intervention. The ranking was placed very visibly on the web site. The comparison application was used with nearly the same frequency. The focus in this area of the application was, as could be expected due to the ranking, the weekly comparison. In the ranking area, the focus stayed mainly upon the ranking comparison between the households, or, in short, on the current rank. Exceeding the expected, the users were also highly interested in the previous rank, which leads to the assumption that they tried to get better at saving energy.

5.5.4 Usage of sub sites tips and to-dos

From 449 sessions in total, the web application registered no activities from 399 of those on the ’to-do’ site, and from 381 on the ’tips’ site. This contrasts often visited sites like the dashboard, where only 21 sessions had no events. A total of only five visitors used the the ’to-do’ feature.

The following two graphics (number 5.16) show all activities and mouse paths on these two sub-sites made by anyone during the experiment. The yellow lines are the paths for stage one, while blue stands for stage two. As can be seen, these sub sites can be ignored as they were hardly used at all. On commonly used sub sites, the map view would be so dense that the site itself would not be recognizable any more. This is clearly not the case for the two sub sites mentioned before.

(a) Sub site 'tips' **(b)** Sub site 'to-dos'

Figure 5.16: path maps of the sub sites 'tips' and 'to-dos'

5.6 Analysis of the consumption

The following section deals with the impact of the intervention onto the behavior of the users. This is why it is necessary to differentiate the experiment into the two stages and examined them in detail on their own.

5.6.1 Days of the week

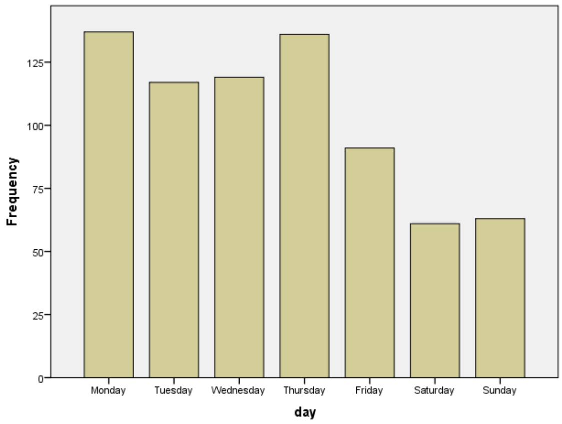
In this thesis all processed consumption informations were assigned the unit kWh per week, because the intervention for the users are also displayed to the user in this unit. Due to this, it is necessary to know if the user visited the website in the first half of the calendar week, or at the end of it, because the intervention will show its impact in the current week or in the week after the access.

If the impact reaches a high enough level, and if the user's accesses are distributed in a relatively equal manner, it is possible to verify the impact's existence for both weeks. This is true, even if the impact itself only lasts for only one week. It is important to avoid the wrong assumption, that, only because an effect can be seen during two weeks, it also exerts it's influence during those two weeks.

day

		Frequency	Percent	Valid Percent
Valid	Monday	137	18,9	18,9
	Tuesday	117	16,2	16,2
	Wednesday	119	16,4	16,4
	Thursday	136	18,8	18,8
	Friday	91	12,6	12,6
	Saturday	61	8,4	8,4
	Sunday	63	8,7	8,7
	Total	724	100,0	100,0

(a) Frequency of weekday



(b) Bar diagram of weekday

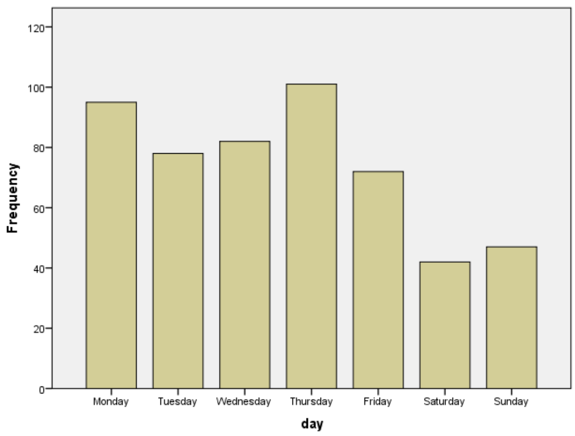
Figure 5.17: Visits per weekday over the whole experiment

During the whole period of the experiment, the most visits take place in the first half of the week, which can be seen in figure 5.17. This is interesting due to multiple reasons. First of all, it can be assumed that if there is a consumption decrease it is visible after the first calendar week. In addition, it is possible to estimate the intensity and the effect of the reduction better than in normal cases.

day

		Frequency	Percent	Valid Percent
Valid	Monday	95	18,4	18,4
	Tuesday	78	15,1	15,1
	Wednesday	82	15,9	15,9
	Thursday	101	19,5	19,5
	Friday	72	13,9	13,9
	Saturday	42	8,1	8,1
	Sunday	47	9,1	9,1
	Total	517	100,0	100,0

(a) Frequency of weekday



(b) Bar diagram of weekday

Figure 5.18: Visits per weekday over stage 1

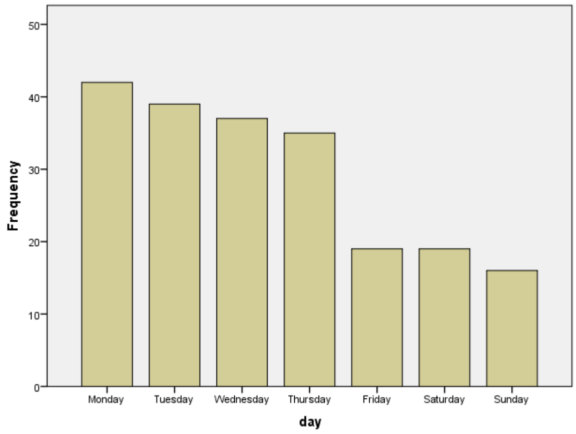
Regarding the second stage of the experiment, most of the users accessed the web application in the first half of the week. Thursday is the strongest day of the week 5.18.

In stage two, the difference between weekend and first half of the week is even stronger than in stage one (graphic 5.19). The first days in the week accounted for nearly the double amount of hits in comparison to the second half of the week.

day

		Frequency	Percent	Valid Percent
Valid	Monday	42	20,3	20,3
	Tuesday	39	18,8	18,8
	Wednesday	37	17,9	17,9
	Thursday	35	16,9	16,9
	Friday	19	9,2	9,2
	Saturday	19	9,2	9,2
	Sunday	16	7,7	7,7
	Total	207	100,0	100,0

(a) Frequency of weekday



(b) Bar diagram of weekday

Figure 5.19: Visits per weekday over stage 2

This leads to the conclusion, that if there exists an effect in the second week, the reason for it can also be, that it is the continuation of an effect of the first week, in contrast to the effect originating in the second week.

Additionally, the user may have already undergone a separate learning effect, because the new aggregated values are visible on Monday. The participants accessed the application more often on Monday in stage two than in stage one. The reason for this may lie in the new ranking calculations, which, in stage two, were conducted on Monday.

5.6.2 Hypothesis 1: The attitude of a user towards renewable energy influenced the intensity of activities on sub sites.

The question in this hypothesis is, if there exists a correlation between the attitude and the activity. In this case, the click events on the sub sites were declared as 'web', 'energy' and 'compare'. It is tested, if the personal attitude of a user is an influential factor for the web application usage. To confirm this hypothesis, a correlation analysis was needed. The parameter 'attitude', which is the attitude concerning renewable energy of a user, as shown in 5.5.1 is normally distributed. Due to that, it is possible to apply a Pearson correlation [Pearson, 1895].

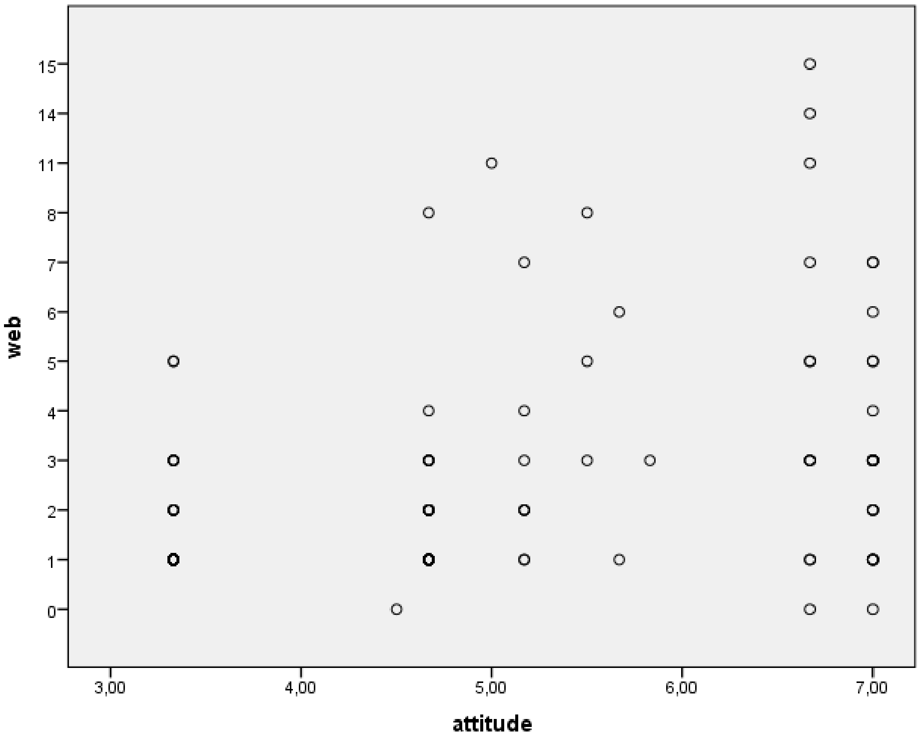
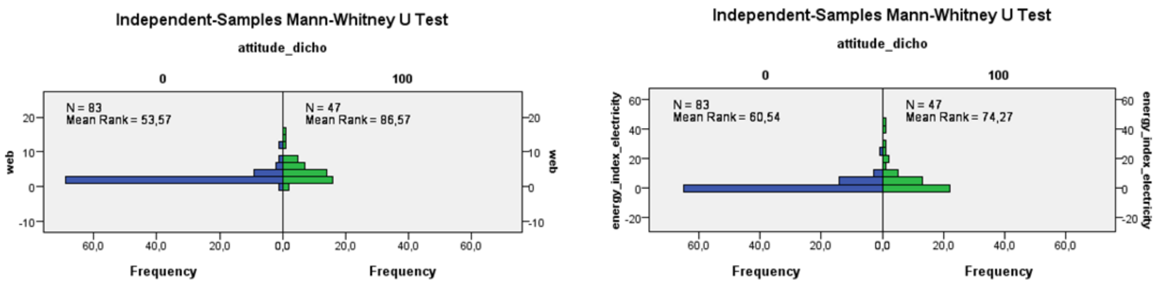


Figure 5.20: Scatter plot for web and attitude

In graphic 5.20 a slight correlation between 'attitude' and 'web' is shown. This is exemplary for all activities. For the activity web exists a highly significant, average correlation (r=.404 and p=.000). The correlation turns out to have a lower value for the activities 'energy' (r=.285, p=001) and 'compare' (r=.293, p=.001). Both results are highly significant.

To classify the impact of the correlation, a difference analysis was also made. Therefore, the attitude was divided into low and high attitude by its mean (M = 5.0033, SD = 0.10127). For web (U(83,47)=130, p=.000) and electricity (U(83,47)=130, p=.039) it could be confirmed that there are differences between the groups with low or high attitude, as can be seen in Figure 5.21. For compare (U(83,47)=130, p=.107) no significant difference could be observed.



(a) Mann-Whitney U Test for attitude & web **(b)** Mann-Whitney U Test for attitude & electricity

Figure 5.21: Attitude and Activity

5.6.3 Hypothesis 2: Intensive usage results in higher energy reduction

To receive evidence, or at least a hint on energy reduction, it is necessary that certain preconditions are fulfilled, as it was already discussed in 3.4.3.1. For example: it is not possible to work with absolute values. Due to that, non-private users and incomplete or invalid records were removed.

To assume, that this approach is valid, it has to be verified, if the values for the previous weeks provide no significant differences. Hypothesis one showed, that their differences do exist between the two stages of the experiment, so it is necessary to consider both stages separated on their own. For both stages it is true, that activities on sub sites ('web', 'energy' and 'compare') are examined via difference consumption. Due to the reason, that difference consumption values are not normally distributed, was it necessary to work with a non parametric test. In this case, the Kruskal-Wallis Test [Kruskal & Wallis, 1952] was used. It turned out to be possible, because the activities are ordinal-scaled variables.

5.6.3.1 Stage 1

As already mentioned, it is necessary to verify, if the difference consumption of the previous week had significant disparities in relation to the current week. This was not the case: web p=.737, energy p=.223 and compare p=.370. In the first half of the calendar week, the users visited the web application on earlier days, therefore it can be assumed, that if there is a significant difference between the group of users, regarding their activities, it would be shown in the current week. This is the case, as shown in graphic 5.22.

With certainty, this applied only for the activity 'energy' (p=.011). The intensive usage of the sub sites web (p=.130) and compare (p=.348) did not have an impact on the consumption behavior.

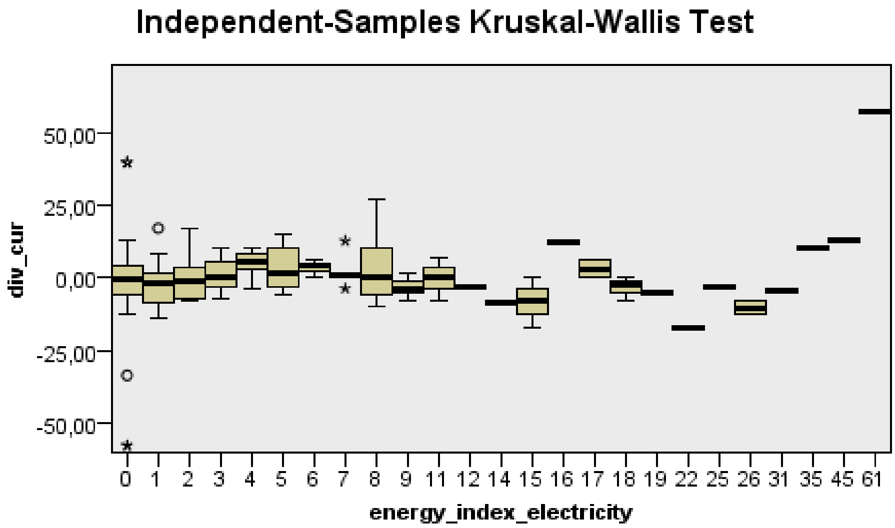


Figure 5.22: Kruskal-Wallis Test for div_cur and electricity

Also, one week after the visit, an energy reduction can be observed in combination with the activity 'electricity' (p=.018). For the other activities, no significant differences can be ascertained ('web' p=.630, 'compare' p=.469).

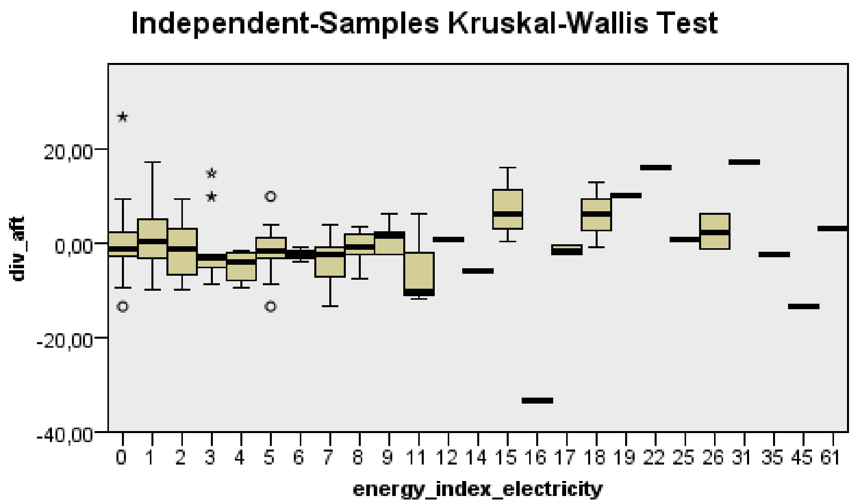


Figure 5.23: Kruskal-Wallis Test for div_aft and electricity

Two weeks after the visit of the web application no differences turned out to be significant ('web' p=.714, 'energy' p=.242 and 'compare' p=.840). This means, that there are no more reductions. On the other hand, this did not lead to any 'YoYo' effects, because their were no significant differences into the other direction. That is why it can be said that a ongoing effect exists, because it continues to have an influence for at least two weeks.

5.6.3.2 Stage 2

In stage two, as well as in stage one, it is necessary to verify if there are any significant differences between the user groups in the week before the visit on the web application. This is not the case: 'web' p=.070, 'energy' p=.144 and 'compare' p=075.

In stage two the session duration lasted shorter than in stage one. This also can be seen in the results of this calculation. There, 'web' was the activity, that shows a significant difference in relation to the energy consumption (p=.017). Web had, on average, fewer click events than 'energy' and 'compare', but there were no significant results for these activities ('energy' p=.583 and 'compare' p=.140). The interpretation of the results indicates, that the intervention is more efficient, and the information was easier available and understandable for the user.

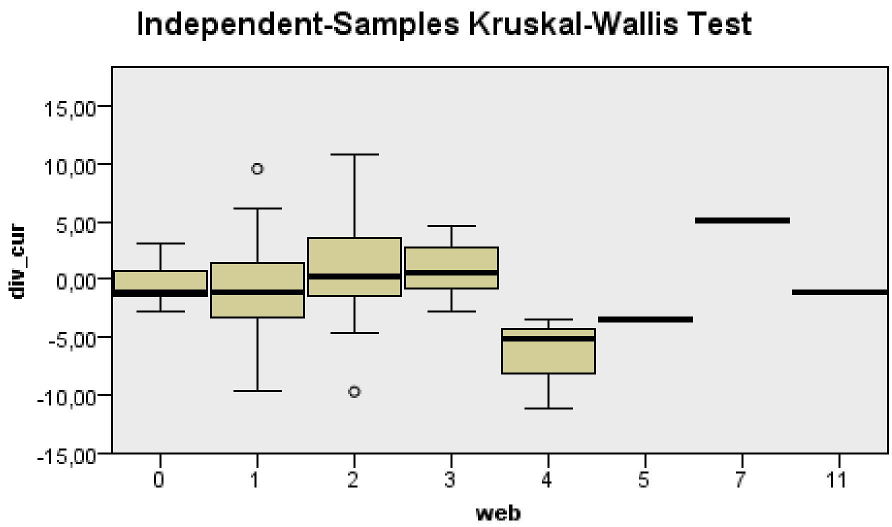


Figure 5.24: Kruskal-Wallis Test for div_cur and web

In stage two, the day of the visit was also an important indicator for further interpretations. The amount of users, who visited the web application in the first half of the week increased even more compared to stage one. This happens at the cost of a lesser amount of users that used the application in the second half of the week. This leads to a reduction of users that influence the following week, and also impacts the result. There are no additional significant differences ('web' p=.255, 'energy' p=.380, 'compare' p=.382). This suggests, that as already mentioned in stage one, there were no fall backs to previous consumption behaviors.

Quite the contrary is the case. Two weeks after the visit of the web application, another significant result could be found, regarding the activity 'web' (p=.039). With these results, a careful statement can be made, that it is possible to argue, that a sustainable energy reduction, with a longer lasting measurable effect, was achieved. For the activities on the sub sites 'electricity' (p=.116) and 'compare' (p=.427) no differences could be calculated.

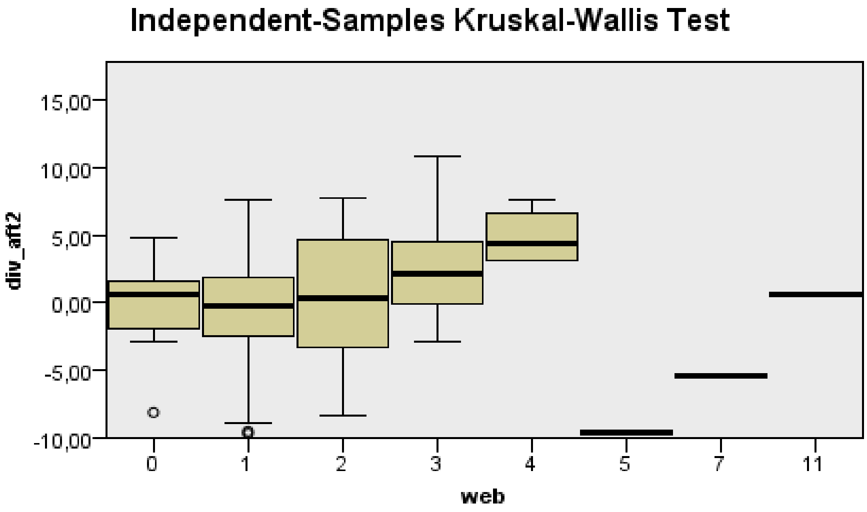


Figure 5.25: Kruskal-Wallis Test for div_aft2 and web

In order to demonstrate this difference, graphic was 5.26 created. It shows the differences between power users (group 1 - blue) and users, who visited the web application a few times or not at all (group 2 - orange). Power users are users who attend the website with at least seven to 140 hits. Due to the fact, that the group of power users, with a cardinality of 21, is a rather small one. The graphic is not able to show more than a delicate trend. Because of this, each household exerts a much larger influence upon the group values. The second group was randomly picked among the other users. For better comparability, attention was paid to the household size.

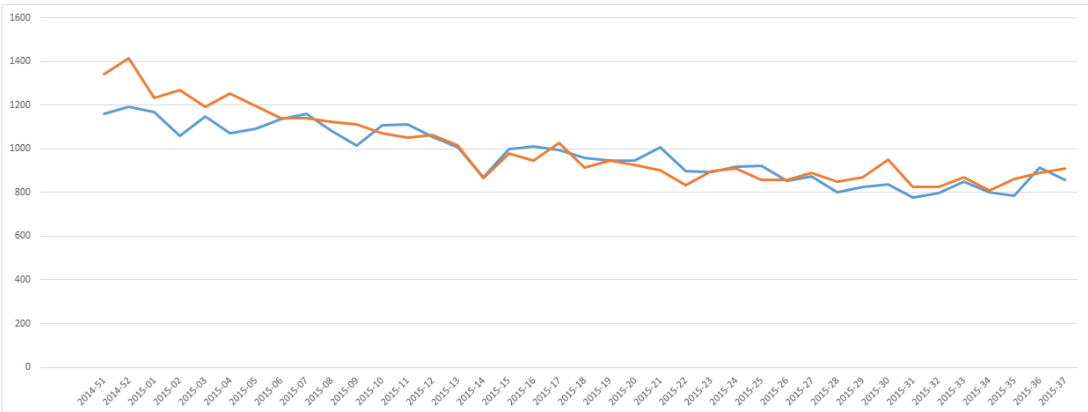


Figure 5.26: Consumption of sample groups

Figure 5.26 starts with calendar week 51, in which every household had smart meters installed. At this time, some users already had access to the web application. Before calendar week 51, the website registered the highest visitor numbers. That is the reason why initial differences could have been caused by the web application. With the drop of the hits on the application, both groups approach to each other over time. From then on both, groups behave nearly identical until June, where usually only power user accessed the website. It should, however, be noted, that in summer times there are fewer possibilities to initiate a consumption reduction in comparison to winter months.

5.6.4 Hypothesis 3: The duration of a session decreases in stage 2

The assumption behind this hypothesis is, that the efficiency of the intervention in stage 2 is higher than in stage one. This consideration is also described in technical literature: if a user does not only get factual feedback (in our case the absolute consumption values in kWh) but also a conclusion and rating of it (in our case the background colors of stage two), the user is more inclined to trust the intervention, instead of checking the values himself.

The variable 'duration' is not normally distributed (Kolomogorov-Smirnov Test p=.000). For this variable, it wasn't possible to work with parametric tests as fig 5.27 shows.

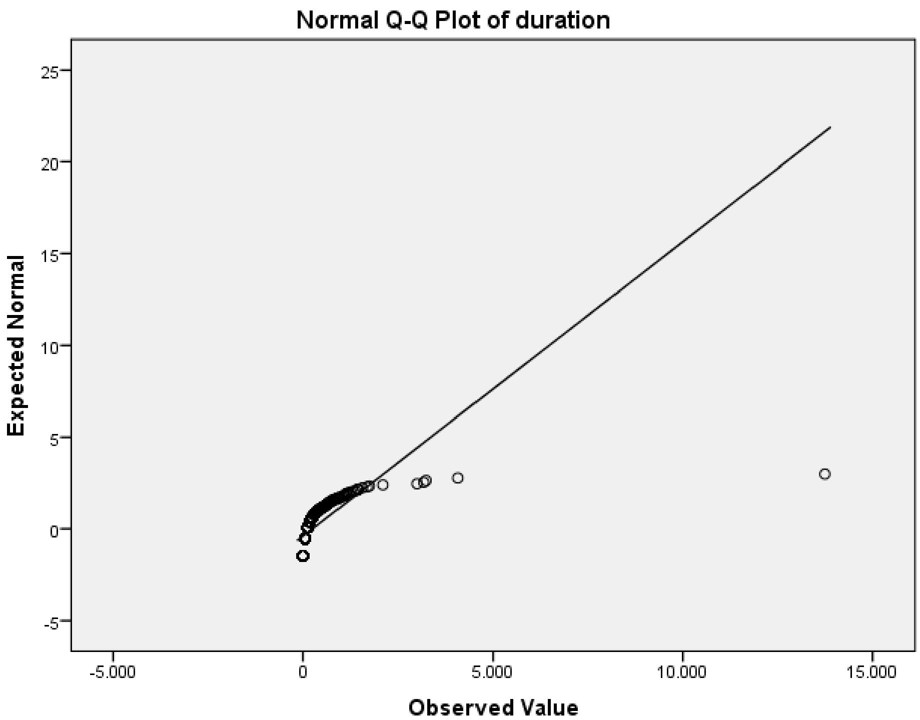


Figure 5.27: Normal Q-Q Plot of duration

Because 'duration' is a not normally distributed variable, and 'stage' is a dichotomous variable, the Mann-Withney-U test was used [Mann & Whitney, 1947]. This nonparametric test for independent samples compares the central tendency of two groups. The hypothesis, that the duration of sessions in stage two decreases could be confirmed (U(517,207)=724, p=.006 fig.5.28).

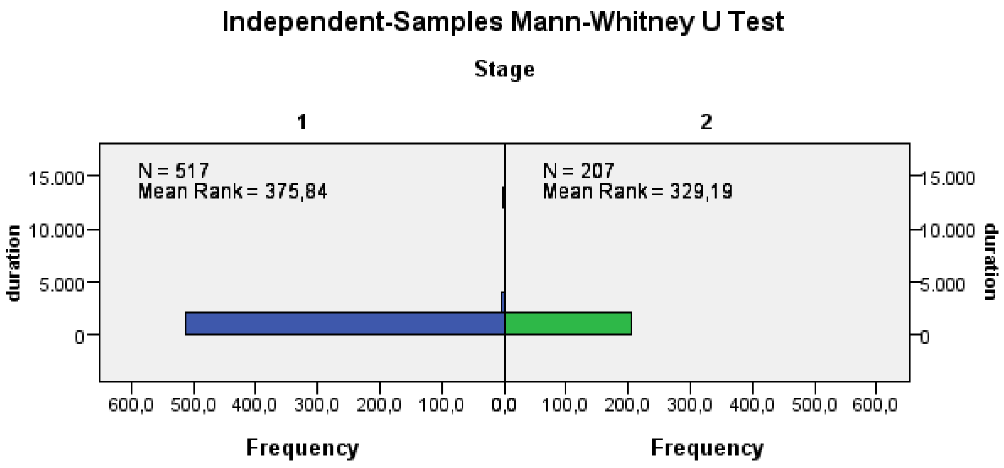
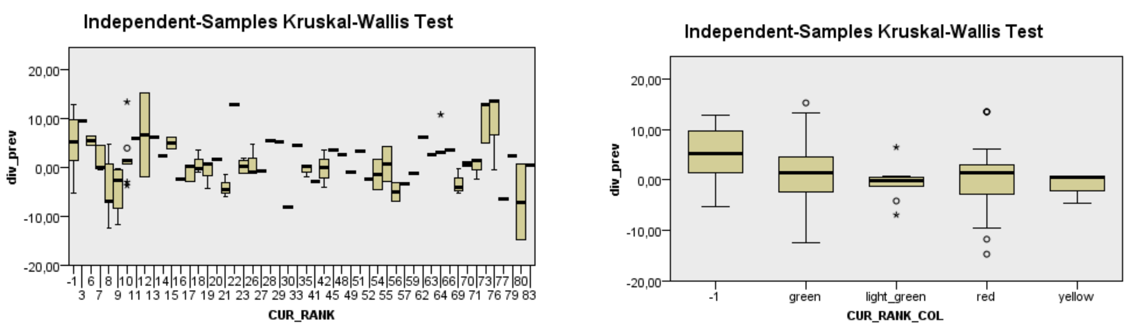


Figure 5.28: Mann-Whitney U test for duration

5.6.5 Hypothesis 4: The ranking has an impact on the consumption

To be able to confirm this hypothesis, the same preconditions have to be fulfilled as in hypothesis 3. All further calculations are related to stage two, because the ranking intervention only exists since stage two. Like before, only complete and valid records were part of the calculation.

In contrast to the previous evaluations, the value of the previous week is already significantly different in relation to the grouping of the ranking. A possible explanation for this result could be the highly significant correlation to attitude (r=.302, p=.007). The detected correlation can be considered as high. This suggests that the consumption of people, who already showed a positive attitude towards renewable energy, would result in a better rank. This finding is reinforced by a highly significant value (p=.000).

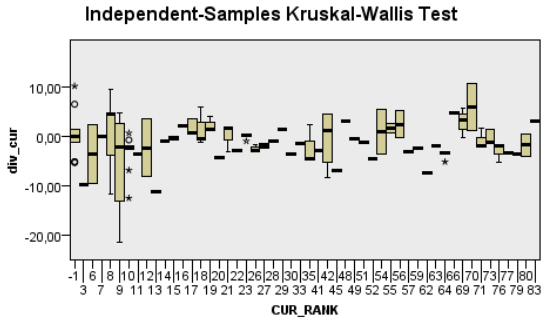


(a) Kruskal-Wallis Test for div_prev and rank **(b)** Kruskal-Wallis Test for div_prev and color

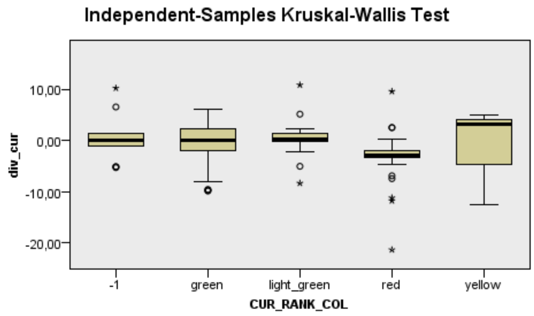
Figure 5.29: Ranking findings for previous week

Due to the reason that the background color is connected to the rank in the calculation on the web application, it was not surprising that, as well as in the previous calculation, the result is also highly significant (p=.006). The result of the current difference consumption showed a highly significant outcome (rank p=.000 and color p=.006), but other influential factors could not be defined more closely. Due to this, it is difficult to come up with a well-founded recommendation.

Furthermore, two-sided asymptotic significances could be found. Nevertheless, there still



(a) Kruskal-Wallis Test for div_cur and rank



(b) Kruskal-Wallis Test for div_cur and color

Figure 5.30: Ranking findings for current week

are strong indicators, that the rank could have an impact on the after effect of intervention. In the previous hypothesis there were tendencies, that the reduction time increases, and, in contrast to the background color (p=.944 after one week and p=.856 after two weeks), barely did not meet the two-sided significance (p=.053 and p=.063). If one could identify more distinct influencing factors, a reevaluation of the results would be possible.

Chapter 6

Conclusion and Outlook

In the end, it can be said, that this experiment produced thoroughly positive outcomes. However, it must also be pointed out, that the difficulty, to persuade users to use the web application permanently, remains. It was not possible to explain to the users, that this web application is intended to be a valuable tool to improve their energy consumption behavior. Due to this the users did not have an incentive to use the website. The following feedback of one user also indirectly contains this statement: 'Frage: Wie kann ich nun meine Rechnungen einsehen? alte/neue? [original]', 'Question: How I am able to access my bills? old/new? [translation]'. Maybe with access to their own accounts and other necessary information a higher number of interested people could be achieved. Those interested people can, of course, only originate from a group, that already naturally uses web applications. The amount of those people does not match the amount of all customers of an energy provider.

In some cases clearly positive results were observed in regards to power savings. These findings showed, in which areas the usage of the web application had an impact on the behavior of the user. It also showed, that the effect increased with Persuasive Technologies. This is especially important regarding mobile devices.

An overview on the key findings follows:

- In average, the users are male, young and have a higher level of education
- Industrial users have, as expected, an immensely higher and more stable consumption profile than private users
- The majority of the users visited the website just once. The incentives to revisit the web application may have been too unappealing for them.
- 26% of the users used a mobile device to get access to the web application, even though it was not a responsive web page.
- The attitude towards renewable energy did have an impact on the usage of the web application. This is true for the duration on the one hand, and the activity on a single web pages on the other hand.
- The sub site 'electricity' was the most popular and also the most used web page. Also, it featured the highest amount of activity. The users focused on the graphical diagrams.

- The web page 'compare' was used more often in stage two, than in stage one, whereby the rank was obviously an important source of information for the users.
- Tips and to-dos were not used at all.
- The dwell time on the web application decreased in the second half of the experiment. This could be the result of the higher efficiency of the intervention.
- The more intensive usage of the web application correlates significantly with the savings. In stage one the activities were related to the electricity overview, and in stage two the usage indicators were the activities on the dashboard. The sustainability of these savings are possible only in short-to-medium term, so it lasted only for a few weeks.
- The question still stands, if the ranking is an influential factor on its own, or if more influential factors exists. The reason, that the dwell time decreased during stage two, is, with a high probability, due to the ranking. Due to the lack of a control group, no definitive statements can be made. Nonetheless, the ranking should be evaluated more precisely, because there are some hints, that it is possible to achieve an ongoing stimulus for energy savings.

6.1 Proposals for action

Due to the fact that this thesis was part of a company experiment, proposals were made for the 'Kärnten Netz GmbH'. The following points were the suggestions, they got from the universities:

- There is a lack of motivating factors for the customer, that could possibly achieve a predicted return on the web application. The aforementioned customer information (for example bills), as well as the attitude towards saving the environment can be used as motivational factor. After all, it was shown, that the personal attitude of a customer can have an influence towards his usage of the web application.
- At any rate, a mobile app or at least a responsive website should be made, because even though the handling was very bad on mobile devices, they were used quite often. An important fact to mention is the efficiency of the intervention for this kind of application.
- Tips and to-dos can be disregarded. If the continuation of these features is wanted, the web page to-dos should be streamlined, and connected to the energy overview.
- Due to the strong activity on the electricity overview in the area of the graphical display, a personalized input mask could be interesting.
- There are two ways to help the consumer orient himself. One is the helping information, if one's own power usage is lower than the overall mean. The other way lies in simplified depictions of factual feedback.

6.2 Proposal for further research

In conclusion it can be said, that some effects could be shown, and also potential for improvement could be identified.

To confirm and to quantify these effects, further studies are needed. The herein presented results for the attitude effect are of an exploratory character, because the amount of records from actual users did not approach a reasonably satisfying level.

Additionally, the amount of true savings that could be achieved with this method, has to be evaluated with a higher amount of power users.

Unfortunately, no survey regarding the competitiveness of the users was conducted. With such a survey, the ranking could have been more thoroughly investigated. Even though, such a survey was suggested, the energy provider did not want to annoy its customers with too personal questions.

The absence of a control group was caused by the circumstances of a real time experiment. Especially the competitive factor for users and its impact on the decision making process should be verified.

The lack of a survey at the end of the experiment, and the lack of a control group is regrettable, but due to the decent number of users who stayed until the end, and due to the findings of the project, it can be declared that the experiment altogether was a success.

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