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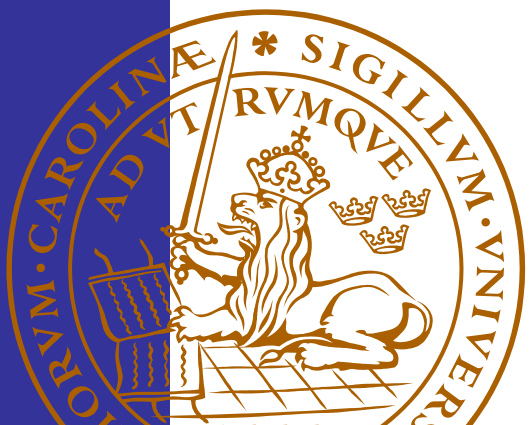
Test of a Home Energy Management System at E.ON

An evaluation of users' expectations and experience

Sofia Björnehaag

Master's Thesis

Energy Sciences
Department of Energy Sciences
Lund University - LTH
Box 118, 221 00 Lund, Sweden



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Box 118, 221 00 Lund

www.ees.energy.lth.se

Abstract

A SIFO-survey ordered by E.ON has shown that more than every fourth person in Sweden feels that they have poor knowledge and control over their energy use, and that four out of ten would like to be more aware and to have better control over it. A solution is to provide the householders with feedback of their energy consumption. Studies have shown that householders can reduce energy consumption with 5-20% having feedback on their energy use.

An increasing energy consumption and development of the sustainable community demands a more efficient energy use. This has lead to many policy measures e.g. requirements on energy feedback to consumers and measures for the energy suppliers to achieve energy savings among their customers. Energy Company E.ON has the ambition to be in a leading position in the development of the sustainable community. They are currently building a house with eight climate smart co-operative apartments in Västra Hamnen, Malmö. One of the main reasons is to find solutions for future energy challenges which demand engagement from both energy supplier and consumer. The climate smart apartments will be equipped with Home Energy Management (HEM) systems, to enable for the householders to get better knowledge and control over their energy use. The HEM System that is to be installed in the homes is under development and to test its functionalities and usability before installation, a R&D trial with twenty friendly test users was carried out in the test users' own homes.

The evaluations of the test users' expectations and experience of the HEM System were carried out partly as a quantitative study in the form of a web survey and, partly as a qualitative study through face-to-face semi-structured interviews.

The evaluations showed that the test users had in general high expectations on the HEM System and it was further shown that the system met most of their expectations. Through the HEM System, the test users experienced a better thermal comfort at home, they increased their energy-related knowledge and made changes in their energy use patterns. The study also showed that the HEM System provided better control of energy use and that it provided the tools for the users to achieve energy savings.

Keywords: Energy feedback, Home Energy Management System (HEMS), Energy efficiency, HEMS user-experience, Smart Home system, Load demand.

Sammanfattning

En SIFO-undersökning, som beställts av E.ON, har visat att mer än var fjärde svensk anser sig ha dålig kunskap och kontroll över sin energianvändning och att fyra av tio svenskar skulle vilja vara bli mer medvetna om och få bättre kontroll över energianvändningen. En lösning är att erbjuda energikonsumenterna återkoppling på sin energiförbrukning. Studier har visat att konsumenter som får återkoppling på sin energianvändning kan minska den med 5-20%.

En ökande energianvändning och utvecklingen av hållbara samhället ställer allt högre krav på bättre och effektivare energianvändning. Till grund av detta har många politiska åtgärder vidtagits t.ex. krav på återkoppling av energianvändning till konsumenter och åtgärder för energileverantörer att uppnå energibesparingar hos sina slutkunder. E.ON har som energibolag ambitionen att vara ledande i utvecklingen av det hållbara samhället, för närvarande bygger de bland annat ett hus med åtta klimatsmarta bostäder i Västra Hamnen, Malmö. En av de främsta anledningarna är att skapa möjligheter för att hitta lösningar på framtidens energiutmaningar, vilka kräver engagemang från både energibolag och konsumenter. De klimatsmarta bostäderna kommer att utrustas med Home Energy Management (HEM) system som möjliggör för hushållen att skapa sig mer kunskap och få bättre kontroll över sin energianvändning. Det HEM-system som ska installeras i bostäderna är under utveckling och för att testa dess funktioner och användbarhet innan installation så genomfördes ett FoU-test med tjugo testanvändare i deras egna hem.

En utvärdering av testanvändarnas förväntningar på och användareupplevelser av HEM-systemet genomfördes dels som en kvantitativ studie i form av en webbenkät respektive som en kvalitativ studie genom personliga halvstrukturerade intervjuer. Det visade att testanvändarna generellt hade höga förväntningar på HEM-systemet och att systemet uppfyllde de flesta av deras förväntningar. Genom HEM-systemet upplevde testanvändarna en bättre värmekomfort i hemmet, de ökade sina energirelaterade kunskaper och åstadkom förändringar i sättet att de använde värme- och elenergi. Studien visade även att HEM-systemet gav användarna bättre kontroll över sin energianvändning och ett verktyg för att uppnå energibesparingar.

Nyckelord: Energianvändning återkoppling, Home Energy Management System (HEMS), Energieffektivisering, HEMS användarupplevelser, Smart Home system, laststyrning.

Preface

This study was carried out as a final step for the Master of Science in Environmental Engineering with specialisation in Energy Systems at Lund University. The study comprises 30 ECTS and was conducted in collaboration with energy company E.ON Sweden, within the research-field "Thinking Energy" Sweden.

I would like to give a special thank to Jurek Pyrko, my supervisor at LTH and Carina Claesson, my supervisor at E.ON. Jurek has given me great tips and advises throughout the study. He has been positive, encouraging and willing to help out and discus my thesis-related questions. Carina has been very keen on getting me familiar with the project within Thinking Energy. She has given me plenty of information about the project and great tips for the study. Throughout the trial we've had many laughter and thoughts on how to proceed with the test users' experience study.

Also many thanks to all persons who were involved in Thinking Energy and "Employee Trial" at E.ON. You made me feel most welcome from the beginning and as part of the project. Thanks to you I've learned many new things about business projects and working in a project team.

Sofia Björnehaag
Lund, October 2012

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Definitions applied in the master thesis

Home Energy Management (HEM) System – A system for energy use control at home.

Smart meter – An electrical meter that measure electricity consumption in intervals of an hour or less and acts as a node for two-way communication between supplier and consumer.

Smart metering – Metering system using smart meters.

Energy feedback display – A digital display presenting energy use feedback.

Smart tariff – Type of electricity pricing with varying electricity price and (optional) load demand price.

Time tariff – Type of electricity pricing that is varying in time.

Sustainable community – Communities that are planned and built in order to promote sustainable living. Sustainable living, in this case, focus on environmental and economic sustainability.

Friendly user – Refers to a test user that has a connection to the product being tested and will therefore likely act friendlier concerning the product and problems that might arise during the test.

Likert scale – A psychometric scale often used in questionnaire research, to measure respondents' attitudes.

Smart plug – A plug placed in the wall socket that measures electricity consumption of an connected appliance and which can be remotely controlled to be switched on/off.

1 Introduction

1.1 Background

The development of the sustainable community and the increasing energy consumption has lead to higher demands of a more efficient energy use. The European Council state that the energy efficiency should be improved and primary energy consumption reduced by 20% compared to projections, by year 2020. To succeed, it is required that the community, businesses and individuals contribute with their part for a more efficient energy use.

E.ON is a energy company with the ambition to be in a leading position in the development of the sustainable community. They are currently building a house with eight climate smart co-operative apartments in Västra Hamnen, Malmö (see Figure 1). One of the main reasons is to find solutions for future energy challenges that demand engagement from both energy supplier and consumer. The smart apartments will be equipped with Home Energy Management (HEM) Systems to enable for the householders to better control their energy consumption. The homes will also be equipped with, among other things, over fifty different measure points that will provide information about energy use of power and heat, temperature fluctuations and gas and water consumption. The homes will provide information for developing and testing different energy solutions and thereby gather important knowledge of how to build new energy smart homes and retro fit already existing ones. E.ON provides energy-efficient technology but how the householders' are using energy plays a large role for achieving energy savings. The householders will be able to control their energy use from a tablet computer or smartphone, they can for example choose not to use energy when the energy prices are high and the electricity grid thereby often heavily loaded. The householders can also make settings in the HEM System and thus let the system use energy in a smart efficient way. (E.ON, 2012)

E.ON is currently developing the HEM System, which is to be installed in the homes at Västra Hamnen, and to evaluated functionality and users' experience of the HEM System a research and development trial with twenty friendly test users was initiated.

Figure 1. Illustration of E.ON's house in Västra Hamnen.

1.2 Objective

The overall aim of this master thesis was to evaluate users' expectations and experience of E.ON's HEM System in research and development stage. A further aim was to evaluate if the HEM System had any influence on the test users' energy-related behaviour and a possible change in the users' level of energy-related knowledge.

1.3 Methodology

The master thesis was mainly preceded in three stages. Firstly, a literature study was carried out to find basis for the user experience studies. Secondly an evaluation of the test users' expectations was performed and thirdly an evaluation of the test users' experience of the HEM System was made.

1.3.1 The study of users' expectations on the HEM System

The evaluation of the test users' expectations on the HEM System and their energy-related knowledge before the trial was performed as a quantitative study in the form of a web survey using the tool, Netigate. The questionnaire was sent to nineteen test users who had three weeks to respond during February 2012.

The questionnaire consisted of statements that the respondents were to consider (see Appendix A). Most of the statements had a scale of one to seven, where one represented "disagree" and seven "strongly agree". The respondents were given an opportunity to explain their answers by writing comments to each statement. In order to evaluate the strength of the respondents' answers a weighting model was used, according to Likert scale. The alternatives on the "disagree side" represented the weight -3/3, -2/3 and -1/3, which stands for "-3", "-2" and "-1". The alternatives on the "strongly agree side" represented weight 1/3, 2/3 and 3/3 which stands for "+1", "+2" and "+3". The weights of all the negative respectively positive answers were added together and divided by the number of respondents in order to calculate the strength of the negative response side ("level of scepticisms") and respective the positive response side ("level of conviction") of the whole sample.

Example of how the Likert scale was calculated:

	Disagree						Strongly agree
Answer alternative	1	2	3	4	5	6	7
Number of respondents	**0**	**2**	**0**	**5**	**3**	**4**	**4**
Weight	-3/3	-2/3	-1/3		+1/3	+2/3	+3/3
Weighted response	-0	-4/3	-0		+3/3	+8/3	+12/3
Weighted scepticism	-4/3					Weighted conviction	+23/3
Strength scepticism	-7.4%					Strength conviction	+42.6%

The survey responses were also analysed according to Lantz (1993), assuming that: words have a similar meaning to different people, all people are able to place themselves in a category or scale, the investigated phenomenon is significant and has similar meaning to all, all respondents get the same question, that is, they are subjected to the same stimuli that are perceived in the same way.

The response rate of the expectation survey was 18/19 = 94.7%.

1.3.2 The study of users' experiences of the HEM System

The evaluation of the test users' experience of the HEM System was carried out as a qualitative study through face-to-face interviews. The interview method chosen was a semi-structured, meaning that, questions have been asked in specific order with varied open and fixed answers (Lantz, 1993). The interview questions were written with the understanding that all test users during the trial had followed instructions to test the HEM System from different perspective. The questions addressed the installation process, the graphic design of the apps, using the HEM System, service and features included in the HEM System, energy-related knowledge and behaviour and also integrity (see Appendix B for interview questions).

All interviews were recorded and listened to afterwards and then written down closely. The interviews responses were analysed in order to find common denominators. Processing of large quantity of interview material can lead to a number of disadvantages. It might be difficult to ensure multiple dimensions simultaneously since interview responses often are sequential and comprehensive (Lantz, 1993). The raw interview material was analysed according an interpretation of Lantz (1993) method for qualitative data processing to avoid incorrect interpretations. The interview texts were firstly encoded by abstracting and finding summary words or symbols for section of words, this without losing the meaning of the answers. This procedure generated categories and dimensions of the interview responses that reflected the interview content on a more systematic level. The interview texts, summarized into categories and dimensions, were compiled in order to be able to find nuances and relationships between the responses. To be able to draw conclusions based of the compositional data clear adjectives such as: good, bad, sad and funny were sought. Using these descriptive words, the respondent's attitude on various issues was judged. Example of an interview question: "What do you think about the iPad app graphic design?" Two respondents answered as follows:

> "I think it is good, both instantaneous with the "energy bubbles" that are very visual and clear and as I said, about the landscape view, the trend curve is clear."

This respondent was considered positive regarding the graphic design, this evaluation was made on the words "good and clear."

Another user said:

> "I am both for and against it in a way. It is easy but not groundbreaking and innovative."

This respondent was considered to be uncertain of the graphic design. This evaluation was of course made on "for and against" but also "easy but not groundbreaking."

The total number of interviewed test users was eighteen but the response rate of the interview questions varied, mainly due to three reasons:

1) All interview questions have not been asked during the interview due to lack of time.
2) The respondent was not able to answer a questions, e.g. due to equipment malfunctioning or because they had not tested the system according to instructions.
3) The answer could not be interpreted in a proper way.

This means that results from the interviews study presented as e.g. 12 out of 14 users, denote that the answers from fourteen users were gathered and possible to interpret in a correct way.

The response rate of the experience study was 18/20 = 90.0%.

2 Theory

The theory section addresses some policy aspects related to energy efficiency, smart metering and energy feedback and also theory regarding smart grids. Furthermore, the section addresses more thorough theories on energy feedback and how the feedback can affect consumers to achieve energy-related savings and behavioural changes.

2.1 Policy and energy feedback

One of the first steps to provide energy consumers with energy feedback was smart metering. It was first proposed in the 1970's but it has only in last decade become fully developed (Darby, 2010). In the European Union smart metering has reached large commercial interest, in 2010, the present and future investment was estimated at 51 billion Euros (Darby, 2010). In 2006 an interconnection between the metering system and better energy use was established in the European Union. EU ratified the Energy end-use efficiency and energy services directive, 2006/32/EC (EC, 2006). The purpose with the directive is to make it easier for energy consumers to understand and control their energy use. The directive specifies requirements on the information that customers should get regarding their energy use. Article 29 states:

> "In order to enable for final consumers to make better informed decisions as regards their individual energy consumption, they should be provided with a reasonable amount of information thereon and with other relevant information, such as information on available energy efficiency improvement measures, comparative final consumer profiles or objective technical specifications for energy-using equipment, which may include 'Factor Four' or similar equipment. It is recalled that some such valuable information should already be made available to final customers under Article 3(6) of Directive 2003/54/ EC. In addition, consumers should be actively encouraged to check their own meter readings regularly."

In June 2011 the European Commission presented a proposal for a new energy efficiency directive, stating that member states should introduce measures for the energy suppliers to achieve energy savings among their end-customers on 1.5% compared to last year sales. Demands on individual metering of power, gas and district heating were also stated in the directive, (Energimyndigheten, 2011) meaning that the energy suppliers must take on various measures to make it possible for the end-customers to both reduce their energy consumption and get individual metering. In June 2012 the Swedish Parliament approved the government bill on "active hourly metering for electricity consumers." That means that customers who sign contracts that require hourly metering should get it for free. It is incumbent on the electricity supplier to notify the network operator that a contract, including hourly metering, with the electricity consumer has been reached. The network operator then has three months from the time of the notification to change the metering method to hourly metering (Marcelius, 2012) which means that smart metering now is implemented in Sweden.

Many policy measures have, in other words, been taken to achieve a better and more efficient energy use, and these measures will hopefully contribute to an increased knowledge and better energy use by the end-consumers. Schwanzer et al (2010) state that energy consumers can through automation control systems and optimization of energy services co-control their environment together with their policies and energy supplier, and also work together to achieve higher level of energy efficiency.

2.2 Smart Grids

Smart grids are a solution of how future electricity grids are going to manage the electricity demands and power production, especially from renewable energy sources. The power production is today mainly centralised to large power plants and it is controlled by the upcoming energy demand. Today

the produced electricity is transported unidirectional to regional grids and distribution grids. (ABB, 2012 a) The smart grids should mainly provide better reliability, security and efficiency than the old electricity grids. This by decentralise power production and make it possible for energy consumers to become energy suppliers and make renewable energy more accessible, affordable and appealing (Mulvaney & Robbins, 2012). The power production from renewable energy sources is more varied and unpredictable e.g. wind farms can only produce power when it is windy, and the production will also be geographically more spread. These aspects require greater demands on the electricity grid, reserve power plants and energy storage. Renewable power production also demands that the electricity consumers adapt their energy use to the production. This can e.g. mean that the industry or private consumers could stop using energy while the load on the grid is high, which requires smart meters and smart control systems (ABB, 2012 a) like the HEM System evaluated in this study. The smart meters are a step towards the smart grid (Darby, 2010).

Hagen (2010) means that the smart grids can engage electricity consumers to use energy more efficient by enabling access to information and automation of their energy use. Smart technologies e.g. smart meters, smart thermostats and smart appliances will provide real-time information that customers and utilities can use to understand energy consumption patterns and to understand when energy efficiency has the greatest impact.

Smart grids will be built with many different blocks, one is the electrical car. The grids needs to be developed to be able to manage plenty of electric cars being charged at once, but the fully loaded cars can also in the smart grids work as energy storages when the supply of electricity is low (ABB, 2012 b). Homes e.g. with solar cells which generate electricity will also work as building blocks. The homes will have smart meters that enables for both buying and selling electricity (ABB, 2012 a) and they will hopefully also be equipped with HEM Systems to provide tools for better energy efficiency.

Smart tariffs and load shifting

Smart grids and HEM systems enable the use of time varying tariff pricing and thereby control of the total energy demand and time-peak energy consumption. A study by Martiskainen et al (2011) have shown that consumers felt that smart meters and real-time displays could encourage people to change their behaviour, especially with introduction of time-of-day pricing which give people a financial incentive. Trials made in the UK to test whether tariffs for electricity use could shift electricity load have shown effects on shifting up to 10%. The magnitude of the shifting effect varied with the type of trial. One of the trials showed that smaller households, with one or two persons, generated larger effects. (DECC, 2011)

Integrity

Issues regarding customer integrity have arisen along with the development of smart meters and HEM Systems. Some of these new metering systems will be measuring appliance specific data e.g. when people are watching TV or making coffee, which in turn also mean that peoples' behavioural patterns can be interpreted from their energy data. Darby (2010) means that installations of smart meters in Scandinavia and Italy have been uncontroversial but that there are growing reports of backlashes against smart meters from customers in the Netherlands, California, Texas and elsewhere. The metering systems are perceived as intruding with one's privacy and also providing increased bills and costs due to new equipment (Darby, 2010).

2.3 Energy feedback

Energy is in many different aspects invisible to the household members. It is an abstract force entering the house often through hidden wires and it is often difficult for consumers to link specific behaviour

to their energy use since energy-related behaviours often are part of inconspicuous routines and habits (Burgess & Nye, 2008). For Swedish people the two main reasons to save energy are: saving money, 51 percent, and environmental aspects, 40 percent. Female respondents, 47 percent, rank environmental aspects as the main reason for saving energy. The male respondents, 51 percent, rank money saving as the main reason for saving energy (SIFO, 2011).

The energy use can be made visible for the householders through feedback on digital displays. Visualization of the energy feedback is a rather new technology and there is still a need for more knowledge about how the energy feedback data should be presented in the best way to motivate to energy savings (Schwanzer & Fensel, 2010). It has been shown that there is a need for better energy feedback in Sweden. Last year E.ON ordered a SIFO-survey regarding Swedish households' energy use, energy-related knowledge and feedback. The survey was carried out between 28th of November and 8th of December 2011 with two thousand respondents. The survey showed that more than every fourth person, 27 percent, in Sweden consider themselves to have poor knowledge and control over their energy use. It was also found that four out of ten, 38 percent, would like to be more aware and to have better control over their energy use. The survey also showed that young people in ages 15-29 were most interested, 65 percent compared with the national average of 54 percent, to learn how much energy appliances at home consume. Young people, 45 percent, did also in a wider range admit to having poor knowledge and insight regarding energy use (SIFO, 2011).

According to Darby (2001) energy feedback can basically be divided into: direct feedback, indirect feedback and inadvertent feedback. Direct feedback is available directly on demand for example by reading a smart meter or looking at a digital display. Indirect feedback is basically processed data on frequent electricity bills sent out to customers. Inadvertent feedback refers to learning by association for example by social learning from community energy saving projects or from when new electrical equipment e.g. solar panels are installed at home (Darby, 2001).

Many studies have shown that feedback of householders' energy use can lead to reduction of energy consumption (Fischer, 2008). Darby (2001) has looked at 38 different studies regarding energy feedback and concluded that direct feedback is the most effective form. Studies show that direct feedback can lead to 5-20% reduction of household energy use. Studies on provision of energy feedback to consumers by Burgess and Nye (2008) have shown support for energy savings between 5-15% depending on quality and type of feedback provided. The variation of measured energy savings reflects, among other things, different types of equipment used, social and climate circumstances and the conduct of the trial. How successfully the energy displays engage and maintain interest of the consumers plays an important role since the overall impact is a product of consumers who chose to use the interface and individual savings from increased knowledge. (Darby, 2010)

2.3.1 Different ways to present energy feedback

How the presented energy feedback is understood is affected by the method of presentation, which also can affect the achieved energy savings (Karjalainen, 2011). Energy feedback can be presented in many different ways some are: real-time energy use, historical comparison, community comparison and goal setting.

Real-time energy use

According to a study by Schwanzer and Fensel (2010) energy consumers want to be able to read their energy consumption in real-time units or at least timely consumption data. Many want to be able to read their consumption though a website and a few want the information offline through a monthly bill. Presenting feedback of real time energy use in watts can give the users valuable insight of their

energy use. It can help the users to become more aware of what specific appliances at home consume and which effect they have on the total energy use. Real time energy use could also be presented in terms of e.g. money units/hour or environmental impact/hour. (Karjalainen, 2011)

Historical comparison

A common way to present energy feedback is through historical comparison of the consumer's own prior energy use with current energy use (Karjalainen, 2011) (Hallin, Lindstedt, & Svensson, 2007). The historical comparison can be on annual, monthly, weekly or daily basis. When making historical comparisons it is important to make the consumer aware that the weather, especially in the Nordic countries, affects the energy consumption to a great extent or to display weather compensated energy data. Advantages of historical comparison have been proven to be that consumers find it easy interpret and understand this type of comparative feedback. Various studies have also showed that customers have a great preference for comparisons with historical data. Disadvantage suggested by some reports are that consumers do understand the energy feedback but that it does not lead to any energy-related behavioural changes. Another disadvantage is that historical comparison only tends to motivate consumers with increased energy consumption. Consumers whose energy consumption already has decreased do not tend to take a closer look in to their energy-related behaviour. (Hallin, Lindstedt, & Svensson, 2007)

Community comparison

Community comparison refers to energy feedback of the consumers own energy use compared with other households' energy use. Studies of community comparison have shown that consumers can be motivated to change their energy-related behaviour by being inspired by similar households that are consuming less energy (Hallin, Lindstedt, & Svensson, 2007). When comparing energy use between households, it is important that similar households are compared with each other. This since energy use is significantly affected by type of building (year of construction, living space and heating systems), number of family members, and geographic location. It is useful to compare the household with a database average to get the most accurate comparisons possible (Karjalainen, 2011).

Karjalainen (2011) state that a critical aspect, in terms of energy comparison with similar households' energy uses, is that the motivation to save energy may decrease if the consumers feel that they are already doing enough, for example if they believe that they are using less energy than previous years or compared to similar households. Karjalainen state that consumers possibly can be motivated to keep good energy conservation by a reward system or through some form of "advanced level" of the energy feedback system. Another disadvantage with community comparison is that it can be difficult to gather data that is necessary for correct a comparison (Hallin, Lindstedt, & Svensson, 2007).

Goal setting

Energy consumers might be motivated to save energy by setting a goal to aim at. The energy saving goal could be set by the householders themselves or from outside the household. The goal should be suitable for the household and be possible to reach, different households have a varying potential for savings, some have very limited while others have very high potentials. The consumers should in order to reach their goal be given energy saving advice and be given the tools to monitor their energy use (Karjalainen, 2011). Advantages with goal based feedback is that it will not involve problems with creating community comparison groups and the feedback will be personalised for the household (Hallin, Lindstedt, & Svensson, 2007).

2.3.1.1 Kilowatt-hours, watts and environmental impact

Energy feedback can basically be presented in terms of kilowatt-hours, watts, money units or environmental impact. A study by Hargreaves et al found that it is important that consumers provided with energy feedback in terms of kWh or CO_2-emissions have the knowledge and interest of the meaning of a these units. Consumers have stated that both kWh and CO_2-emissions were meaningless since they were thought of as abstract figures. Presenting energy use in terms of money units were found to be of the highest interest (Hargreaves, Nye, & Burgess, 2010) and valued more (DECC, 2011). Schwanzer el at (2010) have also found that energy feedback shown in money units generated the highest interaction rate from users, followed by real-time graphs showing immediate changes. Karjalainen (2011) have found that problems with understanding prototypes of energy feedback displays mainly involved two issues. Firstly, many people are unfamiliar with scientific units leading to difficulties understanding the difference between W and kWh. Secondly, many people did not understand how CO_2-emissions are related to energy use. Presentation of costs over a period of time was shown to be most valued by the consumers (Karjalainen, 2011). Presenting the cost of energy use also makes it easier for customers to understand the meaning of the energy consumption in figures of kWh (Hallin, Lindstedt, & Svensson, 2007).

Non scientific graphic indicators can also be used for presenting energy feedback e.g. using comparative colours and different kind of shapes. However, studies of replacing regular graphs with graphics in the form of coin bars and houses turned out to be rejected by the test persons as shallow and distracting. The consequence was that the user did not consider the sender as serious (Hallin, Lindstedt, & Svensson, 2007).

2.3.1.2 Appearance of the energy feedback displays

The design of the energy feedback displays has an effect on the customers' engagement, satisfaction and savings (DECC, 2011). How the energy feedback is displayed, the way the devices look and whether they are portable are important factors for the effectiveness of the energy feedback displays (Martiskainen & Coburn, 2011). A field study by Hargreaves et al (2010) showed that for the energy feedback displays to be used they need to look good to fit into the wider household. The information provided needs to be clear, transparent and flexible for the householders to easily relate everyday practices to the feedback and thereby their energy use. The aesthetic appearance of the displays were also shown to be central, if the display was not acceptably good looking it was hidden away and thus lost its function (Hargreaves, Nye, & Burgess, 2010). A study by LaMarche et al (2011) suggests that user-centered design is essential to implemantion and functionality of energy feedback displays. LaMarche et al also argue that further studies needs to be done regarding the link between the interface design elements in energy feedback and the customer interaction with the technology involved. (LaMarche & Sachs, 2011).

2.4 New knowledge and behavioural change through energy feedback

One of the main aims with energy feedback is to provide information for the consumers to get more insight and knowledge regarding their energy use, which hopefully can lead to energy-related behavioural changes. Fischer (2008) means that the consumer, basically, must know about the nature of the problem, the existing options and their respective consequences, in order to judge them in terms of norms and motives. The "Attitude model" describes behavioural change as a causal chain:

Information → Knowledge → Attitude → Changed behaviour

The model states that in order to achieve behavioural changes it is required that the person (recipient) at first is provided with information about the issue. The information will hopefully in turn lead to

newly obtained knowledge. The person will then form an opinion, an attitude, about the new knowledge which can lead to that the person change its issue-related behaviour. The model does not necessarily mean that increased information flow will lead to changed behaviour. For the recipient to be able to absorb information and translate it into action he or she is often required to have some basic knowledge on the subject. (Kiefer, LeBlanc, & Feldman, 1994) The attitude model is widely used among people that are studying energy-related and environment-related behaviours and it is supported by empirical studies. Sociological and anthropological research does however suggest that the model neglects the important dynamics regarding whether and how households are using the feedback (Hargreaves, Nye, & Burgess, 2010). Numerous studies and experiments have been conducted on how different types of feedback can visualise households' energy use. Some examples are more informative energy bills, energy labelling of household appliances, information and advice via the media and now by in-home digital energy feedback displays. The majority of these studies are based on the assumption that the energy feedback raises awareness about energy use and may therefore motivate individuals to take action to reduce their energy consumption (Hargreaves, Nye, & Burgess, 2010).

Information provided

The information provided has been shown to be of great importance. A study by Karjalainen (2011) has shown that even if energy consumers are motivated to save energy they are often short of the information they need to make sustainable decisions about their energy use. Almost the only way to provide the customers with a direct link between their actions and its results is by presenting breakdown of their energy use, e.g., for specific rooms, specific appliances, or for different times of the day, this create awareness of the relevance of individual actions (Fischer, 2008). Consumers need more information especially related to what specific appliances at home consume. Breaking down energy use can help the consumers to make the right decisions about their energy use and to understand the relevance of individual actions (Karjalainen, 2011). Hargreaves et al (2010) have shown that consumers wanted to learn more about what specific electrical appliances in the household consume and when householders noticed high-energy consumers they chose to dispose them or to use them in a different way. Their study also suggests that the energy feedback displays have helped to promote energy conservation by increasing the daily insight and act as potential stressors when people see that the energy use is ticking money. A study by Schwanzer el at (2010) regarding energy feedback showed that more than half of the participants thought that they would become more energy aware by visualisation of energy use.

Energy feedback displays can show the main energy use information, but further information, advice and prompts are likely to be required if the impact on the consumer is to be maximised. The information provided should be to be clear and presented in an attractive way, it should further be relevant, timely and kept up to date (DECC, 2011). Balanced amount of information provided and providing sufficient information is important, frequent small parts of information appear to be more effective than providing single comprehensive information (Hargreaves, Nye, & Burgess, 2010). Frequent and regular feedback is a key factor to achieve energy-related behavioural changes (Fontér & Wiberg, 2010), and the more often a customer have access to energy feedback the better results (Hallin, Lindstedt, & Svensson, 2007).

Behavioural change

For household members to make energy-related behavioural changes it is essential that the feedback is transparent, easy to understand and adapted to the specific needs of the household (Fontér & Wiberg, 2010). It is also important that the householders get a feeling of control regarding their own energy use (Hallin, Lindstedt, & Svensson, 2007). It is further important that the recipient is motivated to save

energy or willing to put some effort in for achieving energy saving e.g. installing energy a HEM system. For householders to decrease their energy use they must also have the means, motive and opportunity, meaning that they need to know what to do, have reasons for doing it and have the resources to do it. The opportunity refers to having the time to do it, the possibility to pay the costs associated and sometimes the required space at home. Most changes of reducing energy demand tend to be those that require little investment of time and money (DECC, 2011).

Hargreaves et al (2010) found in their study that providing energy feedback mainly leads to three distinct behavioural responses. First, the most common reported was that when the consumers noticed that their electricity use was higher than normal they immediately switched off electrical appliances around the house. The energy feedback displays provided a visual prompt or trigger for behavioural responses. Second kind of behavioural change noticed involved making considered and rational decisions based on feedback, the householders choose not use greedy electrical appliances and ensured when buying new appliances that they were energy efficient. Third change noticed, although much less common, was that the consumers started to think ahead to re-prioritize energy use in order to reduce their consumption (Hargreaves, Nye, & Burgess, 2010).

Karjalainen (2011) state that consumers who are found to have high energy consumption may be good at justifying their own energy-related behaviour by finding various explanations for their high energy use. Karjalainen mean that one may think that the washing machine is used continuously because of a small baby in the family, and sees this as the principal reason for high consumption. People find different reasons for their behaviours regardless of whether they are true or not. Energy consumption feedback make contributing factors for high energy use visible and erroneous conclusions about the energy use can be avoided (Karjalainen, 2011).

To engage consumers about energy feedback displays it has been shown that the consumers often find confirmation of energy savings more useful than using the display to initiate savings, and that the display can be used to check if appliances are switched off before going to bed or leaving the house (DECC, 2011). An important issue regarding the use of energy feedback displays is that they after an initial period of interest and frequent use, their use fall to practically nothing (Hargreaves, Nye, & Burgess, 2010). But there are also studies that show evidence that displays have an enduring impact even if only used for a short periods, this through changed habits and investment in efficiency measures (Darby, 2010).

2.4.1 Summary of energy feedback theory

The different alternatives to present energy feedback mentioned in this study are summarised in Figure 2, the evaluated HEM System's presenting methods are marked in grey.

Energy feedback designs which provides multiple options of how the feedback is presented has been shown to work best (Fischer, 2008), the HEM System evaluated in this study provides many different feedback alternatives as shown in Figure 2. Besides providing the energy consumers with different energy feedback alternatives the feedback should also according to theory be: clear and transparent, frequent, electrical appliance specific and personalised for the household.

Type of feedback

Real-time	Historical comparison	Community comparison	Goal setting

Frequency of the feedback

Year	Month	Week	Day	Hour	Minute/real-time

Indicators

Power (W)	Consumption (kWh)	Cost (SEK)	Environmental (CO_2-emissions)	Other indicator (colours)

Aggregation

Household total energy use	Disaggregation by room	Disaggregation by type of electrical appliances	Disaggregation by electrical appliances

Type of visualisation

Textual	Table (Numeric)	Chart (Bars/line/pie)	Graphic visualisation (energy bubbles)

Figure 2. Different energy feedback alternatives (partly from Karjalainen, 2011). Alternatives marked with grey are used in the evaluated HEM System.

2.4.1.1 HEM System and behaviour

The HEM System should likely have an impact on the users' energy use. Figure 3 illustrates how the "Attitude Model" to changed behaviour in combination with the HEM System could affect the users. The outer circle represents the users' possible way to change behaviour and the inside of the circle represent how the HEM System could affect the users during the different steps. By using the HEM System the users will frequently see their energy use on the iPad or iPhone, this will give them the opportunity analyse and reflect over energy use. Their new reflections can lead to a changed energy-related behaviour or investment in energy efficient measures. Changes in behaviour could e.g. be to tumble dry the laundry less often than before. Investment in energy efficient measures could e.g. be buying energy saving lamps or, like in this case, making HEM System settings to use energy in a better efficient way. The changes and/or investment will have an impact on the energy use. The cycle can be continued again and again, through the users seeing, reflecting and changing their energy use.

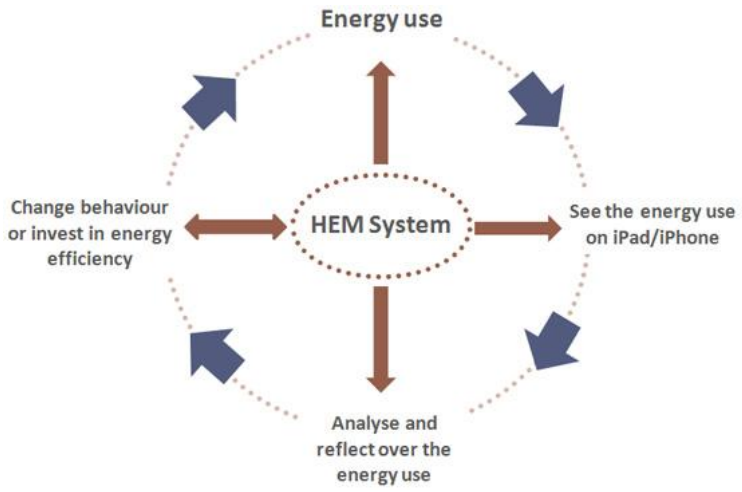

Figure 3. How the HEM System can affect the user's energy use. The outer circle represents the user and the inside of the circle how the HEM System could affect. (Partly from Darby, 2008)

Besides the effect that the HEM System could have on the users' energy use, consumers also need to have the means, motive and opportunity and get a feeling of control over their energy use to achieve changes in energy use. For the changes to be maximised the consumers should also be presented with further energy-related information, advice and prompts.

3 The trial

E.ON is developing the Home Energy Management (HEM) System with two co-partners, a supplier of alarm systems and HEM solutions and an app interface developer. Before taking the new HEM System to the market the functionalities had to be secured, therefore a R&D trial with twenty friendly test users was initiated. The test users were introduced to the trial when the HEM System was at an early stage of the development, the system and its components had basically never been tested together before the trial.

3.1 The HEM System

The HEM System is primarily being developed in order to be installed in E.ON's new-built homes in Västra Hamnen, but also for use in existing homes as in this R&D trial. The main features of the HEM System in the trial were: transparency and control of electricity and heat use (also by remote), smart tariffs and load control and a simple alarm system.

3.1.1 HEM System components and their functions

The HEM System consist of different components to enable analyse and control over the users' energy use. The HEM System components used in the test users' homes were:

- 1 iPad + E.ON app
- 1 iPhone + E.ON app
- 1 gateway
- 1 electricity meter reader
- 10 smart plugs
- 5-15 smart thermostats
- 1 temperature sensor
- Alarm components
  - 1 Smoke Detector
  - 1 PIR Cam (movement detector with camera)
  - 1 Door Contact
  - Remote Controls
  - 1 Key Pad (digital display)

The HEM System was during the trial controlled from an application on an iPad or iPhone. The apps enable control over heat and power use and provide feedback regarding temperature and power use. Feedback regarding the household's power use is gained from the electricity meter reader and the smart plugs. The electricity meter reader is installed on the main electricity meter, and it read the household's total electricity use. The smart plugs are plugged into wall sockets with electrical appliances plugged into them and they read the consumption of the appliances. Both the electricity meter reader and smart plugs passes the consumption data to the gateway. The gateway passes it on to a server, which made the information available for view on the iPad or iPhone (see Figure 4). The communication between components, gateway and server is done in a few seconds. The smart plugs can be switched on/off via the iPad or iPhone and also manually via an on/off diode light button.

The household heat use is controlled via the smart thermostats. These are mounted on the radiators as regular thermostats and equipped with batteries to enable communication with the gateway and thereby enable control from the apps. There are also buttons on the smart thermostats for manual control. The temperature sensor read the indoor temperature and is also equipped with batteries to enable communication with the gateway.

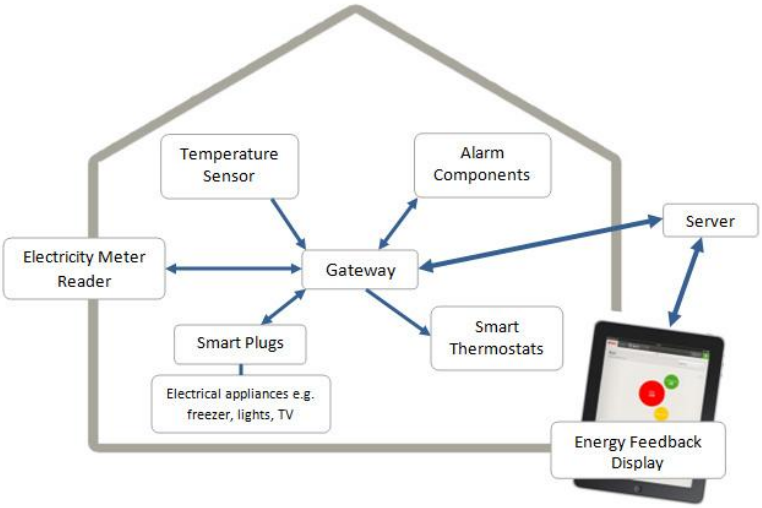

Figure 4. HEM System components and communication.

3.1.2 Main HEM System features

The primary aims of the HEM System are to provide different tools for the users to be able to *monitor, control, analyse and reduce* their energy use. The primary HEM System features tested during the trial are explained below.

Analysis mode

The Analysis Mode provides the users with information on their household's electricity use for all smart plugs, the electricity meter reader and the temperature fluctuation in one room. The users can analyse the electricity consumption in kWh or SEK and from an hourly to a yearly basis. Future users in Västra Hamnen will also be able to analyse their heat, gas and water consumption. The cost feedback presented in Analysis Mode was during the trial not the test users real electricity cost. Although the idea is that the future users will pay according to smart tariffs, the test users did not. To visualize a possible pricing, the price tariff was every day calculated from Nord Pool spot prices with tax addition and energy supplier surcharge.

Heat control

The users can control the indoor temperature via the HEM System app for all smart thermostats at home. They can set different temperatures for different rooms and for different times of the day. The idea is that the users could save heat energy by e.g. setting lower temperatures in the house during daytime when no-one is at home.

Home/Away/Asleep/Vacation and Schedule

The Home/Away/Asleep/Vacation feature helps the users to both control and hopefully reduce their energy use. The users can for four different modes determine when electrical appliances at home should be switched on or off. They can also for the different modes make various temperature settings. The feature make it easy for the users to control their energy use after their "home/away" status which hopefully in turn should reduce unnecessary energy use.

The different modes can also by using the Schedule feature be scheduled on an hourly basis to avoid having to change modes manually.

Saving mode
The Saving Mode is an attempt to test whether smart tariffs can affect the users' electricity consumption and thereby to some extent shift their electricity load. The test users can set Saving Mode for different electrical appliances that they agreed to be switched off due to high electricity prices. They can choose between two different time levels, seldom or often, when the appliances may be switched off but they cannot in any way to control when this might occur since it is controlled by the price tariffs. They can however choose to switch off Saving Mode at anytime.

Alarm
The alarm can be controlled from remote through the iPhone or iPad app, manually or according to the users' schedule. The alarm system was not fully tested during the trial.

3.2 The test users

The HEM System was tested by twenty friendly users in their own homes. All test users were employed by E.ON and the vast majority of them chose to participate in the trial because they thought it seemed interesting. Many are interested in energy-related issues and energy savings. Some are interested in new business opportunities for E.ON and some are involved within the project with the new homes in Västra Hamnen. The test group consisted of ten women and ten men, in the ages 30-55, most of them living in houses with waterborne heating systems.

4 Results and discussion

The result from the expectation survey and the experience study are presented together, divided into sub-chapters reflecting different aspects and features of the HEM System. After each sub-chapter the results are discussed. Results from the expectation survey are often presented in percentage reflecting the strength of conviction or scepticism according to Likert scale. Results presented from the interviews study stated as e.g. 12 out of 14 users, denote that the answers from fourteen users were possible to interpret in a correct way (according to sub-chapter 1.3.2).

4.1 Installation

The HEM System consists of many components, which are to be installed in the users' homes and linked to the iPad and iPhone app. It was shown in the expectation study that the test users were willing to spend quite a long time on different installation processes. The male respondents tended to be more willing to spend a more time on physical installations than the female, but not in the case of installing alarm components. The female respondents tended to be more willing to spend more time on linking components to the app than the male respondents.

The installation of components and linking them to the app should be easy so that future users are able to do this by themselves. The test users were initially supposed to do all installations by themselves, but due to different delays most installations were carried out by two technicians. They configured smart gateways, installed some of the smart thermostats on radiators and they also helped the users to link some of the components to the app. Much later during the trial they also installed alarm components in half of the test users' homes. Some test users reinstalled components and all users have linked components to the apps. 12 out of 17 test users experienced difficulties or frustration during the installations, especially when linking components to the app. They thought this was very confusing

and that the instructions did not seem consistent. Some stated that they followed the instructions precisely, but that they had to do repeat them over and over to get it right.

Many of the test users expressed a concern for the installations of the HEM System components. They argued that the installation process was too difficult for what they believe that a future user will accept. They did however believe that future users will be able to manage the installations by themselves if the linking of components to the apps becomes easier, if there are more and improved instructions and feedback from the system and also if the future users will have the option to get phone support. A few users mentioned that was valuable to be able to get support from the developers and other users via the trial's Facebook-group[1]. One user said regarding the installations:

> "You want to get a confirmation that you're doing it in the right steps."

Discussion
The HEM System users will get their first impression of the system during the installation, it is therefore important that the process runs smoothly for them to get a good impression. The study showed that the test users experienced many difficulties during the installations and the observation is that their frustration due to difficulties affected their early opinion of the HEM System. The study shows that the installations need to become a lot easier. Foremost the linking between components and app must become more user-friendly and function better. Secondly, there need to be additional and clearer user-instructions. More feedback from the app would also help the users during the installations.

4.2 Design

The design of the app and HEM System components are essential for the users to get a good overall experience of the product. A goal during the development of the app has been to create an attractive graphic design and at the same time present clear and transparent information. The expectation survey showed that the test users had high expectations for the graphic design of the apps, the strength of their conviction was 56% while their strength of scepticism was 7%. The survey also showed that the respondents tended to think that clear and transparent information was more important than an attractive design, the strength of their conviction was 30% while the strength of scepticism was 9%.

The experience study showed that 9 out of 18 test users liked the iPad app graphic design, three users thought that it was good enough, five users were found to be doubtful and one user was negative regarding the design. The users who liked the design used words such as: good, clear, nice, funny, attractive, colourful, bright and airy as positive attributes to describe it. The test users who seemed to be doubtful or negative regarding the design emphasized the lack of a "wow factor". They believed that the design was neutral, that it followed an old pattern and that it was not innovative. They had difficulties to pinpoint what was missing but they called for a more intense experience. One user said:

> "I think the design is pretty good, it's nice. But it's not wow."

The first view displayed when starting the iPad app is an overview of the "home" where the "energy bubbles" captures the users' focus (see Figure 5). The energy bubbles serves as indicators of the household's electricity use at the moment. They represent a main part of the graphic design. 10 out of 12 test users were positive to the energy bubbles and six of them were considered to be very positive. 2 out of 12 stated that they did not like the bubbles.

[1] The Facebook group was used to give support to the users and for reporting problems with the HEM System.

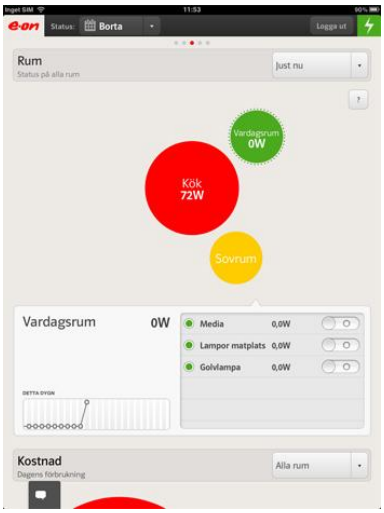

Figure 5. The iPad app home view.

Figure 6. The iPhone app home view.

The experience study further showed that the test users had quite divided opinions regarding the graphic design of the iPhone app (see Figure 6). 6 out of 13[2] users liked the app design and 7 out of 13 were considered to be doubtful. Some users stated that the iPhone app design followed the same design patterns as the iPad app, while others considered the iPad app design to be much better. Some thought that iPhone app design was good and that the smaller format was suitable, while others thought that it was cluttered and not as transparent as the iPad app.

Since one of the main aims of the HEM System is to illustrate the users' energy use it is important that it is presented in a clear and transparent way (see sub-chapter 2.4). The HEM System, through the iPad app, mainly provides two different ways of presenting the users' energy use, through the energy bubbles and through the "Analysis Mode". The users were asked if they thought that the app visualized their energy use in a good way. 10 out of 18 test users thought that the app visualized their energy use in a good way, five users were consider to positive, two users were considered to be doubtful and one user disliked the visualisation of energy use.

Utility design profile

The test users were asked about their thoughts regarding the apps' graphic design and the utility design profile. The respondents' thoughts were scattered; some thought that the design followed the utility profile, while others thought that the apps could just as well have belonged to another company. Some stated that the design did not follow the same design pattern as other apps of the utility, but they argued that this was positive. Some users were unsure of the appearance of the utility design profile.

Design of the HEM System components

The expectation survey showed that the test users in general had low expectations of the design of the HEM System components, but it was clear that the female respondents had higher expectations than the male respondents. The experience study showed that most test users had some complaints about the appearance and shape of the smart plugs. Many thought that they were too large and they were critical of the fact that it impossible to place two smart plugs next to each other in the wall socket. Some considered the smart plugs ugly while others thought that their appearance was acceptable. A

[2] 5 out of 18 test users had never used the iPhone app when interviewed.

few users made complaints about the diode light on the plugs; they thought it was annoying to see small red lights all around the home. Most test users had no complaints on the smart thermostats. Some did, however, not like the smart thermostat display. They stated that one needs to use a mirror to be able to see the display if the thermostat was too close to something e.g. a wall. A few users said that they had to lie down on the floor to be able to see the display. Some also thought that the buttons were hard to use, that it was difficult to know if one had pressed the button or not. A comment from a user regarding the design of components was:

> "We must do something about the design of "everything" visible. For example, the smart plugs are horribly ugly and I will not have them in my home after the test period. They need to be smaller or integrated into the wall sockets."

Discussion

The graphic design of the apps has been an essential part of the development. The study has shown that the design developers have made a rather good job, primarily by the facts that most test users liked the way the app visualized their energy use and that many liked the energy bubbles. Many test users also liked the iPad app design but many users were also considered to be doubtful. It was also shown that the users had somewhat divided opinions of the iPhone app design. All these aspects indicate that the development of graphic design of both apps is on the right track but that they need to be improved.

The study has shown that the appearance of the HEM System components is important for the users. The users want them to be small and preferably not attract any attention.

4.3 Using the HEM System

In order to make the system attractive to future users it is important that it is pedagogically structured, easy to learn how to use and obvious easy to use. The test users were asked about their former experience of using the technology involved in the HEM System, to be able to try and draw conclusions on whether they had difficulties learning how to use the apps. They were also asked about how they were using the HEM System, to get better understanding for further development. The expectation study showed that 12 out of 18 test users considered themselves to be well experienced in using smartphones before the trial, and that only two users had no user-experience. The user-experience of tablet computers was much lower, only 5 out of 18 users considered themselves to have good user-experience and five users had no experience. It was also shown that male respondents had more user-experience than female both in using smartphones and tablets and that female respondents tended to be willing to spend more time learning how to use the apps.

The experience study showed that most test users thought that it easy was to learn how to use the iPad app, but many users also stated that the app could become more user-friendly. Many users did not think that the app was pedagogically structured. They had difficulties to understand where to click or how to use the tablet to locate different features. Some users said that they found new pages and functions late during the trial. It was even found during the interviews, more than four months after the first app release, that some test users still had not discovered some pages and features. Many users experienced a lack of user-instructions for the app and some wanted a more clear design to easier understand where to press to come to another page.

Use, motivation and obstacles

It was shown that the expected use of the iPad app consisted with the actual use (see Figure 7). 61% of the respondents expected that they would use the iPad app a few times a week and 22% thought they

would use it more often. The experience study showed that 56% of the test users used the iPad app a few times a week, and 28% stated to have used it once every day. Some users stated that they were using the system more often in the beginning than they did later during the trial. They stated that they after using the HEM System for a while found settings that worked for them and that they learned how much power electrical appliances consume. These aspects made it less interesting for them to use the system in the later stages of the trial. The test users stated that they primarily used the iPad app to analyse their energy use and to configure HEM System settings.

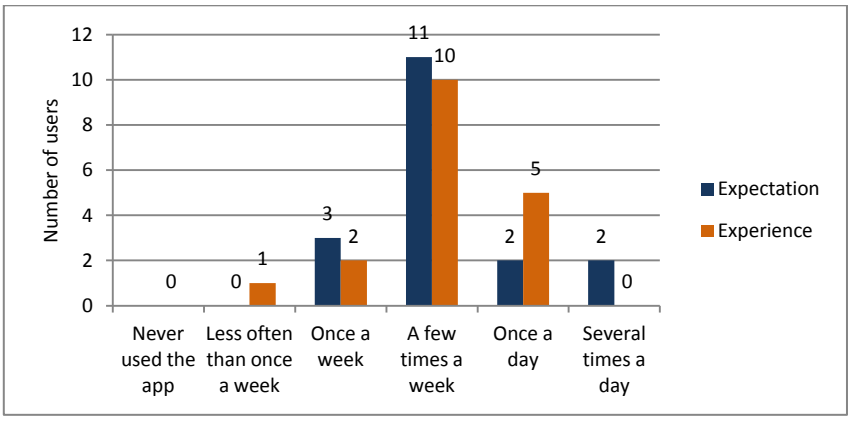

Figure 7. Expected and actual use of the iPad app.

The study showed that the actual use of the iPhone app was lower than expected (see Figure 8). 39% of the respondents believed that they would use the iPhone app a few times a week and 50% believed that they would use it more often. The experience study also showed that 22% of the users used the iPhone app a few times week, 22% had used the app more often and 28% of the test users had never used the iPhone app.

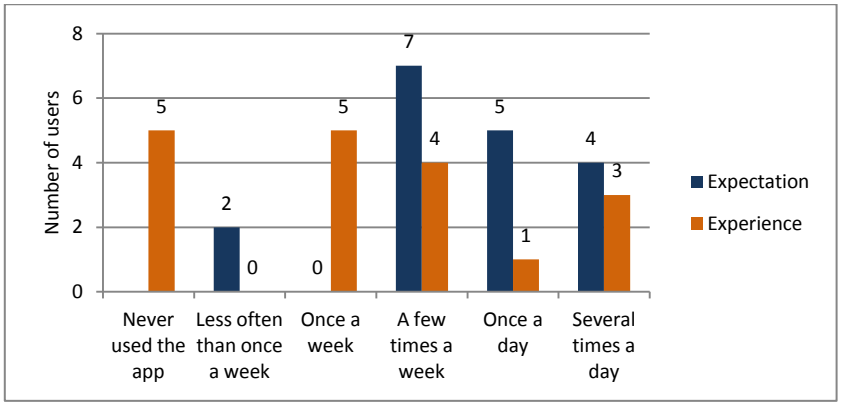

Figure 8. Expected and actual use of the iPhone app.

The iPhone app was primarily used to control and monitor the energy use at home. It was also often used to switch on/off appliances and to change the Home/Away mode. Many users stated that the advantage of the iPhone app was that it made it easier to remote control the HEM System. A few users believed that they probably would have used the iPhone app more frequently if the alarm feature had functioned optimally.

The test users were asked what motivated them to use the apps during the interviews. Analysis of energy use was the feature that motivated the users above all, next is the ability to control and monitor

the energy use. Change of settings was also one of the main incentives. The main obstacles for not using the apps were lack of time and energy. The test users also stated that the motivation to use the HEM system decreased since the felt that it was not a "real test" and because the HEM System was malfunctioning sometimes. They argued that the system did not measure the heat use, that the measured electricity use did not match the invoice, that the electricity prices were not real and that components sometimes were malfunctioning.

The test users were asked some general questions about the HEM System services and features during the interviews, e.g. which services the users were using the most, if they considered any services unnecessary and if they were lacking any services or functions. The top five services and functions that the test users claimed they had used the most were: setting of temperatures, analysis of energy use on the iPad (landscape view), the Schedule, remote control and switching on/off appliances. Most users did not consider any of the services to be unnecessary. A few users stated that the cost diagram (portrait view), the bill tracker and other things that showed electricity cost were unnecessary. They meant that you cannot deduce your real energy cost from them. The test users had many different answers to the question of whether they missed a service or feature. Many lacked feedback and interaction from the HEM System, for instance feedback that showed that a new setting had been applied, if a smart plug was malfunctioning, if the server or the smart gateway had failed or when the electricity price was high or low. Many users also stated they would like to be able to read their heat consumption and some wanted to be able to deduce their total electricity use preferably showed in an "energy bubble". Some wanted additional settings possibilities and features on the iPhone app. They stated that one has the smartphone at hand and that they missed that they could not changes all HEM System settings when not having the iPad with you.

Use by family members

Most test users stated that someone in their family had tested or used the HEM System but only a few of them stated that another family member had used the system frequently. Some test users argued that it indeed was a weakness that all family members were not involved in the trial. The test users said that the interest among other family members was low. Some claimed that the family had been subjected to the problems and that it is understandable that the interest was low. Some believed that the use of the HEM System by family members could have been increased if they themselves had not been so involved, if the electricity cost savings could have been greater and if the alarm function was fully developed.

A few test users stated that their family members had learned how to switch on/off electrical appliances when they due to the Schedule or Saving Mode had been switched off. One test user managed to arouse the interest of the children by showing that the energy use was reduced when big sister was away from home for a couple of days. Another user said that the children checked which of their rooms that consumed the most electricity. One test user made it clear for his son who plays a lot of computer games what it costs when the computer is not switched off. He said: "I forced him to watch the app." Some test users showed the HEM System to colleagues and friends and they all got a positive response. People thought that it was nice that E.ON was working with Smart Home systems.

Discussion

Many users had some experience of using smartphones or tablets, they thought that is was easy to learn how to use the apps but they did not think that they were pedagogically structured. This needs to be taken into consideration during further development.

The expectation was that users would choose to use the iPhone app more often than the iPad app. This was expected since people often have their smartphones close at hand, and though also making remote control more accessible. It was however found that the iPad app was generally used more. This could be explained by the Analysis Mode on the iPad app, since one of the users main incentives to use the apps were to analyse their energy use and the iPad app provide a better analysis feature. Most test users were found to have used the iPad app a few times a week or more, which was considered to be high since the HEM System provides the opportunity to make different settings and then leave the system to run automatically. Some users stated that they were using the apps more frequently at the beginning of the trial. A question that raised by this notion is whether this eventually can lead to the system falling into disuse and if that in turn could lead to less energy savings than if the apps would have been used more frequently. Darby (2010) do, however, state that there are studies that show evidence that energy feedback displays have an enduring impact even if only used for a short period.

The users argued that their motivation to use the apps decreased since the HEM System was malfunctioning sometimes, because the heat use was not measured and due to the electricity cost not being real. This shows that the test users were keen on getting a lot of insight into their energy use and the importance of providing clear and transparent information.

It is a shame that the use among the test users' family members was low, but it is understandable due to many hassles. It is, by this notation, questionable whether the test users' activity during the trial was mostly due to their participation in the trial and how often the average person would use HEM System. It is important that the entire family is involved in order to achieve greater and lasting savings.

4.4 Services and features

Many different services and features are included in the HEM System, the test users did a short assessment of all of them and the main ones were further evaluated during the interviews.

4.4.1 Assessment of services and features

The test users were asked to assess a number of different services and features both during the expectation survey and the experience study. The expectation survey showed that services of high interest were display of real time energy use, display of monthly energy use, setting temperature, setting temperature according to Home/Away/Asleep/Vacation and remote control (see Appendix C for complete assessment). They were also asked in the survey which services they were most curious about, the majority of test users replied that they wanted to be able to control the home. That they wanted to get better control of electrical appliances and especially be able to control the heat at home and preferably by remote control. A few mentioned that they wanted to be able to measure their energy use.

During the interviews the users assessed 31 different services and features that were included the HEM System or might be included in the future. The test users assessed two features connected to heat control as very important, setting of temperature as the most important and display of indoor temperature as third most important. They assessed remote control as the second most important service and two features that provide better control of electrical equipment as very important (see Table 1).

Table 1. The top five services and feature that were considered as most important for the test users during the experience interviews.

	Service	*Not at all important*	*Not important*	*Neither nor*	*Important*	*Very important*	*Likert scale*	*Response rate*
1	Setting temperature	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (26.3%)	14 (73.7%)	86.8%/ -0.0%	19/19
2	Remote control	0 (0.0%)	0 (0.0%)	0 (0.0%)	7 (36.8%)	12 (63.2%)	81.6%/ -0.0%	19/19
3	Display indoor temperature	0 (0.0%)	0 (0.0%)	2 (11.1%)	6 (33.3%)	10 (55.6%)	72.2%/ -0.0%	18/19
4	On/Off electrical appliances	0 (0.0%)	1 (5.6%)	2 (11.1%)	4 (22.2%)	11 (61.1%)	72.2%/ -2.8%	18/19
5	Overview and control of electrical appliances	0 (0.0%)	0 (0.0%)	1 (5.3%)	9 (47.4%)	9 (47.4%)	71.1%/ -0.0%	19/19

During the expectation survey the test users considered tips on saving measures and intruder detector as services of least interest. Program On/Off according to electricity prices (Saving Mode), fire alarm and messages from the energy supplier were also services of low interest. The experience study showed that the users assessed energy saving coach as the service of least interest and displays of environmental impact as second least service of importance. An energy reward system, the bill tracker and messages from the energy supplier were also features of low interest (see Table 2).

Table 2. The bottom five services and feature considered to be of least important for the test users during the experience interviews.

	Service	*Not at all important*	*Not important*	*Neither nor*	*Important*	*Very important*	*Likert scale*	*Response rate*
27	Messages from the energy supplier directly to tablet/ smartphone	1 (5.3%)	2 (10.5%)	6 (31.6%)	5 (26.3%)	5 (26.3%)	39.5%/ -10.5%	19/19
28	Bill tracker	0 (0.0%)	2 (10.5%)	5 (26.3%)	11 (57.9%)	1 (5.3%)	34.2%/ -5.3%	19/19
29	Energy rewards	0 (0.0%)	6 (31.6%)	6 (31.6%)	3 (15.8%)	4 (21.1%)	28.9%/ -15.8%	19/19
30	Display environmental impact	0 (0.0%)	4 (21.1%)	6 (31.6%)	8 (42.1%)	1 (5.3%)	26.3%/ -10.5%	19/19
31	Energy saving coach	1 (5.3%)	4 (21.1%)	7 (36.8%)	6 (31.6%)	1 (5.3%)	21.1%/ -18.5%	19/19

Discussion

Setting temperature was valued as most the important service and display of indoor temperature as third most important, heat control and reasons for the service being of high importance for the users are discussed in sub-chapter, 4.4.2 Heat Control. Remote control was ranked as the service of second most importance and overview and control over electrical appliances as fifth most important service. The expectation survey showed that the test users wanted to get better control over their energy use and the SIFO-survey (2011) showed that 38% of Swedish people want to become more aware and get better control over their energy use. The feeling of control over energy use has also been shown to be important for the householders to achieve behavioural changes. (Hallin, Lindstedt, & Svensson, 2007) To provide control over energy use is in other words a very important HEM System features (see sub-chapter 4.5 Control, alarm integrity for further evaluation).

One of the main aims with the HEM System is to provide the users with information about their energy use. It is therefore interesting that the test users valued services that provide energy information lower after the trial than before the trial. Before the trial the test users valued two services that showed their electricity use as most important, after the trial only display of real time electricity use was valued rather high (see Appendix C for complete assessment). This could be explained by the fact that many test users learned what electrical appliances at home consume and thereby not valuing the energy use information as important after the trial. Another explanation could be that they during the trial found other features to be more interesting and important.

Noteworthy is that the test users valued services that can help/coach them to achieve energy savings of low interest. Reasons might be that they already consider themselves to be well aware of energy-related issues and how one can save energy and then not believing that an energy company can contribute with information that they do not already know. The users did however claim that they wanted more interaction and feedback from the system but they ranked message from the energy supplier as of low interest, which is contradictory. This is presumably telling that they want more feedback and information regarding their own energy use and the system itself. For further development of the HEM System it might, however, be good to add services that gives the users advice and prompts on saving measures, since e.g. it was found in the DECC (2011) study that these aspects are needed for the impact on the consumers to be maximised.

The bill tracker feature was also ranked to be of low importance the main reason is probably that it did not show the real electricity cost. Display of environmental impact was ranked second least service of importance. Some users who were sceptical question how one are to calculate the impact. They do not believe there is a good way of doing it without errors. Some also said that it would not motivate them more than showing kWh itself and thereby not believing the feature to be important.

4.4.2 Heat control

The expectation survey showed that the test users believed that the HEM System would generate a better thermal comfort at home; the strength of their conviction was 65% while the strength of the scepticism was 4%. The expectation survey also showed that quite many of the test users often changed the level of the smart thermostats manually before the trial; the strength of agreement was 39% while the strength of disagreement was 26%. The experience study showed that setting temperature was the function that the test users valued as most important. It was shown to be the function that most test users claimed they used the most and it was also one of the functions that did motivated them the most to use the HEM System. The heat control was, in other words, found to be very important for the test users.

Advantages with the HEM System heat control

16 out of 18 interviewed test users did install the HEM System smart thermostats, those two who did not had different types of heating systems at home. 12 out of 16 test users did after installing the HEM System experience a better thermal heat comfort at home, i.e. a more regular and comfortable temperature. Two of these users directly related this phenomenon to the new thermostats, they meant that the thermostats they had before the trial were old and poorly working. Three other test users said that the comfort level was better when the system was working but that it also during some periods was worse than before the trial. 4 out of 16 test users did not experience a better thermal comfort at home. Two out of these four said that they could not tell whether the thermal comfort was better but they stated that it was not worse.

The test users thought that it was easy to regulate the temperature through the HEM system. Many users did, at first, try different temperature settings to find an indoor climate that suited them, then they let the HEM System control the heating after their settings. Some users stated that a main advantage of setting the temperature via the HEM System was that you could do it from one central for the whole house. The availability increased which in turn also increased their motivation to change the temperature. Another main advantage turned out to be the possibility to set different temperature for different rooms, 15 of 16 test users did find this very valuable. They meant that one often want to have different temperature in different room, for example colder in the bedroom and warmer in the living room. It was though clear from the interviews that this did not work equally well in small apartments and in homes with open floor plan. Some users said that they liked that they did get a good overview of the temperature setting in each room, which probably increased their feeling of control over the heat use at home. A few users said that a main advantage of the heat control features was that the desired temperature was reached and some users stated that being able to remotely control the heating settings was the main advantage. Only one user stated that the energy saving potential was great advantage.

Discussion

The study showed that heat control was very important to the test users, the reasons for this were unfortunately never evaluated further during the interviews. One possible explanation could, however, be that many users were aware of that heating use is one the largest expenses in a household and that they realised a chance to decrease the heat use cost. Another explanation could be that the thermal comfort affects how we feel and thereby making it important for the users to find a good indoor climate. Many aspects suggests that the test users value features that provides control over their homes very high, the HEM System provides availability and control over heat use.

The heat control should from a customer point of view especially contribute with two advantages, a better thermal comfort and heat energy savings. The fact that 12 out of 16 test users experienced a better thermal comfort after installing the HEM System is evidence that the system works, whether this was due to the HEM System, the new smart thermostats or a combination needs to be further evaluated. The HEM System heat control provides a tool for the users to save energy if they for example try to reduce the temperature during daytime. The question is if the users have achieved any heat energy savings and how large they can become, this since temperature regulation is related to thermal inertia which can make it difficult to decrease and then increase temperature during shorter time periods.

The communication problems between smart thermostats and gateway have resulted in many used batteries. One can argue that the smart thermostats in terms of the lifecycle perspective have contributed to a greater environmental damage than if they were not used. The developers of the HEM System has during the trial found solutions to the problem and the smart thermostats are at current stage working properly, and they should hopefully now not lead to any extra environmental or money costs.

Some suggestions on improving the heat control are:

- More feedback and interaction from the app regarding temperature settings
- Possibility to set temperature for dates for example, when going on vacation and knowing when one will come back
- One mode for completely switched off, e.g. when opening windows

4.4.3 Analysis Mode

The Analysis Mode (see Figure 9) provided the test users with feedback about their household's electricity use for all smart plugs and the electricity meter reader and also the temperature fluctuation in one room. They could analyse the electricity consumption in kWh or SEK and on hourly to yearly basis. The expectation study showed that most of respondents expected to be able to read the household's energy consumption in real time (W), the strength of their conviction was 83% while the strength of their scepticism was 0%. They also expected to be able to read their energy consumption in terms of money units (SEK), the strength of conviction was 63% while strength of scepticism was 6%. Only a few respondents expected to be able to read their environmental impact, their strength of conviction was 28% and strength of scepticism 22%.

The experience study showed that Analysis Mode was the feature that the test users claim motivate them the most to use the HEM System. They used Analysis Mode once or more times a week and primarily to analyse their electricity use in terms of kWh. They looked for high power consumers, checked if the electricity consumption differed from normal use and tried to understand consumption patterns. Very few users were using the feature to analys temperature fluctuation and electricity costs. It was during the interviews clear that many users seemed to be interested in and wanted to learn more about their energy use. 10 out of 15 test users stated that they have learned something by using the analysis mode.

Figure 9. Analysis Mode. Upper chart is showing cost feedback for one day. Lower chart is showing power use for one month.

Some users wanted to be able to see the total electricity use of the household as a post on the "Prylar-list" in Analysis Mode, and they also wanted to be able to see their heat and water use as posts. A few users asked for comparing features, to be able to put the own energy use in relation to different aspect. For example one wanted to be able to analyse the outdoor temperature with indoor temperature, to better understand fluctuations of the indoor temperature. Another user wanted to be able to compare the household washing machine with a standard washing machine to analyse if their machine was as good as standard ones. This shows that some test users felt that it was difficult to assess and relate whether their energy use was considered to be normal. A few users stated that the y-axis scale on the analysis graphs showed too many zeros when the electricity use was low, this made it difficult to interpret. It was also mentioned that some axis did not have a unit which made it difficult to

understand what they were showing and that numbers were stated between two lines which made it confusing to deduce the right number (see Figure 9).

Discussion
It is really positive that Analysis Mode did motivate the users the most to the use the HEM System, this since a main aim with the system is to motivate its users to analyse and learn new things about energy use. It is also really positive that most of the users did learn things by using the analysis feature. These aspects strongly indicate that the HEM System has fulfilled one of its purposes.

Studies regarding energy feedback have shown that the average person wants be able to deduce their energy use and potential savings in money units (see sub-chapter 2.3.1.1). Reading of the environmental impact has also been shown to be of great interest. The test users have been shown to differ from average persons, most of them analysed their energy feedback in kWh. They hardly ever analysed the energy feedback in SEK. There are three likely explanations for this, firstly that the users before the trial had better knowledge of the meaning of a kWh the average person. Another explanation could be that the feedback shown in money units was not the users actual cost, which might have made them less interested of analyzing the cost feedback. A third explanation could be that many users late during the trial discovered that one could analyse the energy use in terms of money units. Noteworthy is that users during the assessment of the services valued the display of indoor temperature as a very important feature but only a few used Analysis Mode to analyse the temperature fluctuations. Reasons might be that many users late discovered the possibility to analyse temperature fluctuations or that they were satisfied with just being able to check the indoor temperature.

Some suggestions on improvement of the Analysis mode are:

- Show units on all axes.
- Make sure that y-axis scale is easy to interpret; sometimes there are too many zeros.
- Do not state numbers between two lines, this could make it confusing to deduce the right number.
- Show the total electricity use as a post on the “Prylar-list”.
- Add comparison features to increase the possibilities for the users to draw different conclusions and learn more about energy use e.g. community comparison or a form of comparison for standard electrical appliances and maybe heat use and weather comparison.

4.4.4 Schedule

The users can by using the Schedule regulate the heat and control which appliances that should be switched on/off at home according to their own schedule. The feature allows users to save energy by first making some settings and then letting the system regulate the energy use. The expectation survey showed that the respondents expected that they would save energy by using the HEM System, the strength of their conviction was 69% and the strength of their scepticism was 4%. The survey also showed that the test users valued a schedule feature as rather important, the strength of their conviction was 61% while the strength of their scepticism was 0%. It was also shown that some respondents had been or were using timers or remote switches to electrical appliances at homes and that many users often manually changed the level of their thermostats at home. For these users the schedule was expected to be very useful.

The experience study showed that 14 out of 18 test users used the schedule; three of these only used it for heat regulation. It was also shown that the test users valued the schedule function a little less important after using it, the strength of their conviction was 61% while the strength of their scepticism

was 3%. The users were overall satisfied with the scheduling function, they thought that it was easy to understand how to make settings and how to use the schedule. Many of the users tried their way to find a schedule that suited them and then they left the Schedule with the same settings. The study showed that the schedule settings must suit the entire household for it to work well. Families with many family members and families with irregular life had difficulties finding a schedule that worked for everyone. One user stated that the household, because of difficulties finding a suitable schedule, only scheduled the heat. Another user said that he only scheduled short "safe" times when he knew he was asleep and a third user stated that he gave up using the schedule due to his family's irregular life. There are some features that could make the schedule more suitable for different lifestyles. The test users argued that you control different appliances for different reasons. The heat control works well for home/away etc., but that one has more preference for controlling e.g. the lights for instance when you are at home and when it is dark outside. They also state that it is not certain that you want all appliances to be switched on just because you are home but you might for example want the indoor temperature to increase. A solution could be scheduling of heat and electronics as separate groups or even scheduling of various electronics groups e.g. lights, entertainment and kitchen appliances. One test user even proposed the possibility to schedule appliances one by one. Some user would like to be able to schedule more specific than just on hourly basis. A few also wanted to have some sort of timer or random function. They wanted to be able to set when the lights are to be switched on and off or let the HEM System within a time interval turn on and off lights, this as a kind of protection against break-in.

A few test users question whether the temperature regulation in combination with the schedule was working. They said that they could not feel any difference in temperature according to their for example scheduled low temperature at daytime and higher temperature in the evening and lower temperature at night. Explanations for this can be the communication problems between the gateway and smart thermostats. Another possible explanation could be that the system need more time to regulate the temperature to the degree the users wish to reach (e.g. due to thermal inertia).

Discussion

The study showed that many test users were using the Schedule and that they were overall satisfied with the function, but it also showed that people living irregular lives had difficulties finding a schedule that suited them. The test users had many ideas of how to improve the schedule settings, indicating that there should be opportunities to make additional settings.

The users had high expectations that they would save energy by using the HEM System and the advantage with the Schedule is that it provides a simple way for the users to save energy by making settings and allowing the system to manage the energy use. It provides an easy way to get rid of standbys and forgotten switched on lights etc. Possible energy savings obviously depend on how many electrical appliances that are linked to the schedule and on applied temperature settings. The questions is how large the energy savings can become, this need to be further evaluated.

Some suggestions on additional settings or improvements to the Schedule are:

- Scheduling of heat and power as separate groups.
- Scheduling more specific than on an hourly-basis.
- Add a timer or random function.

4.4.5 Saving Mode

Saving Mode was an attempt to test whether smart tariffs could affect the users' electricity consumption and thereby also to some extent shift their electricity load. To thoroughly motivate the test users to test Saving Mode a challenge was conducted during three weeks in April. The challenge was to save the most energy compared to the previous month by using Saving Mode and the winner would receive a smaller prize. The challenge did reflect the purpose with Saving Mode in the aspect that; if the users were to pay according to smart tariffs they would have been able to save money by using the feature. 16 out of 18 test users tried Saving Mode; most of them had it running during the challenge and some even longer. The test users had Saving Mode enabled for appliances such as lights, media appliances, dryers, laundry machines, dishwashers, dehumidifiers, fridges and freezers. They early discovered trouble with Saving Mode taking over and switching off, for example, the washing machine and the dishwasher during the time they were running. This led to clothes soaked in detergent and washing-up liquid getting stuck to the washing-up, which in turn sometimes lead to that they had to restart the washing cycles. Most users then chose to cancel Saving Mode for these machines while a few users instead started to select a "safe" time interval according to the price tariff for their laundry and dish washing. The study showed that many test users thought that Saving Mode worked well for some appliances but not as good as for others. It did work for example refrigerators and freezers but not as good for lights, media appliances, laundry machines and dishwashers, in other word appliances that one want to use when the need arises.

Saving mode vs. control

Besides the fact that Saving Mode did switch off machines when they were running many test users thought that the amount of control, by settings, that Saving Mode provided was enough or at least to start with. Some users stated that one can always switch Saving Mode off. They argued that an energy saving function should be simple to use for people to use it and that more settings can make it confusing. Even though many of the test users thought that Saving Mode did provided enough control it is important to take those who did not in consideration, this both to keep and increase the use. Many test users did in fact switch Saving Mode off after the challenge. During the trial it became clear that some users thought that Saving Mode interfered too much with their everyday activities and routines. Some users for example stated that you want to make dinner before you are hungry and do the laundry when you have the time. One user also stated that it was annoying when the standby for the TV and digital box was switched off since it took long time for the digital box to restart. These activities often coincide with high electricity prices and thereby interference by Saving Mode. The energy saving function did, in terms of these aspects, decrease the users' comfort of electricity use. One user even said:

> "It does not increase my comfort, it reduces my comfort. It gives a small saving but the saving is not high enough."

Another user said:

> "It felt a bit handful that it was cancelled during a wash. So I ran there to match when to throw in a washing before next saving mode. It is annoying that the washing machine stop in the middle. But I checked the bars* so I did fine. But then it's really exciting, I've always been saying "a test is a test indeed" And so when a lamp was switched off when we had guests over and it became dark, I got to say that this is a test indeed."

*The bars are referring to a bar chart showing the price tariffs for each hour during one day.

Energy savings vs. comfort

The expectation study showed that the test users expected to save energy by using the HEM System, the strength of their conviction was 69% while the strength of their scepticism was 4%.

The experience study showed that 15 out of 17 test users believed that they would choose to use energy when it is cheap if they were paying according to a time tariff. Four of these users stated that it depends on how much money one could save. The test users were asked to define when comfort is more important than energy savings, their thoughts were rather scattered. Many users truly believed that comfort is more important than energy savings. Two users stated that energy savings only gets interesting when you achieve large savings. Two others stated that they believed that one can achieve energy savings without decreasing the comfort. One user stated that the thermal comfort was very important and that one can comprise when it comes to electricity use. Another user thought that the thermal comfort was not very dramatic, but that one wants to use electrical appliances when one have the need to use them.

The study of the test users' expectations showed that the respondents valued a function like Saving Mode rather low. The strength of the respondents' conviction was 33% while the strength of their scepticism was 0%. After using the HEM System the test users did rank the function as more important. The test users' strength of conviction of Saving Mode for power use was 53% while their strength of scepticism was 8%. Regarding Saving Mode for heat use the strength of their conviction was 66% and the strength of the scepticism was 0%.

E.ON did an evaluation of Saving Mode and the possible effect of smart tariffs and thereby also load control. The evaluation was made by comparing electricity use and costs between sixteen days in March, not using Saving Mode, and sixteen days in April, using Saving Mode during the challenge. The evaluation showed that there where a slight reduction of total electricity consumption and a reduction of the total electricity price when using Saving Mode.

Discussion

The fact the test users rank Saving Mode as a more important service after using it, indicates that they see potential and value in the feature. The users rank saving mode feature for heat use as more important than for power use. One reason can be that they are more willing to decrease the thermal comfort at home than the power comfort. Another reason could be that saving of heat use can generate larger energy savings though being the largest energy consumer in many homes.

The study showed that Saving Mode works technically, but the question is which incentives future users will have for using the function, is it to save energy, save money or for the good cause. This study shows that people have difficulties changing their daily activities and routines for the purpose of energy and costs savings, even though stated that they were willing to change their energy-related behaviour. It also became clear that the cost savings need to be quite large for the users to want to use the function. Maybe the energy supplier could motivate its customers to shift their electricity load or the save more energy by making larger price differences. Many test users admitted that the Saving Mode challenge did motivate them to save energy, suggesting that there are other ways to motivate energy savings than cost saving. But then again the question regarding daily routines arises.

Some suggestions on additional settings or improvement to making Saving Mode more user-friendly:

- Do not interrupt machines in the middle of a cycle
- More interaction from Saving Mode, e.g. push notifications telling when electricity prices are high or low.

- When the electricity price is higher than x SEK then turn off x machine. And vice versa for low electricity prices. This to give the user the opportunity to self choose when it is worth to use Saving Mode.
- Specify which hours during the day the HEM System can turn off appliances because of high electricity prices.
- Let the HEM System decide when it is good to run the e.g. dishwasher, but with condition that it has to be done a specific time.

4.5 Control, alarm and integrity

Control

An aim with the HEM System is to provide the users with more and better control over their energy use. The users can for example at any time by remote check if they forgot to switch off an electrical appliances that may be fire hazards, which hopefully should increase their feeling of safety. The expectation study showed that the test users did not believe in an increased feeling of safety at home and over the home due to the HEM System, the strength of their conviction was 13% while the strength of their scepticism was 22%. The survey did however show that quite many users thought that it is important to be able to check if unnecessary electrical appliances are switched off, the strength of conviction was 43% and strength of scepticism 7%. As written in sub-chapter 4.4, the test users wanted to be able to control the home, they want to get better control of electrical appliances and especially be able to control the heating and preferably by remote control. One test user said regarding the feeling of control:

> "Imagine how nice it would be to be able to control if the iron or the stove is switched off when you left home and you can't remember if you really switched it off."

The test users were three months into the trial asked if they, at the current stage, felt safe to use the HEM System/if they had trust in the system. 11 out of 16 users answered that they did not have trust in/felt safe to use the system. During the interviews, 14 test users rated their trust of the HEM System at current stage on a scale from one to ten. One representing "Do not trust the HEM System at all" and ten "Fully Trust the HEM System". The mean value did become 6.2. Some users said that the reasons for the low rates were that the HEM System and many components had sometimes been malfunctioning, and that their energy use feedback did not match the electricity bill.

Alarm

The idea with the HEM System is to control the whole home from one unit, and thereby also the home alarm system. The alarm system was not fully developed during the time of the interviews so the users were never asked of their experience of the alarm. 16 out of 18 test users were, however, in favour of having an alarm system in combination with the HEM System. Some argued that it is a good value-added service and some even argued that it is a requirement to make the product attractive for sale in the future.

Integrity

In order to provide for example analysis of energy use and scheduling of heat and power the required data need to be saved on a server, e.g. either provided by the company or on the user's own server. The test users were asked about their opinions regarding integrity and their energy data being collected by their energy supplier. 13 out of 17 test users stated that they did not feel that collecting of their energy use data contracted with their integrity, one user was considered to be doubtful and three users thought that it did contract with their integrity. Many users directly stated that it is important that the

data is handled and used in a proper way and that it does not get in the wrong hands. A few users meant that it is easy to know when to do a break-in if you get hold of the data. But some users also stated that one must be able rely on bigger energy companies like E.ON. 10 out of 15 users thought that is was okay that the company collected their energy data on a detailed level, such as when the TV is switched on and how much it consume. Five users thought that is was okay to collect data on an aggregated level, such as how much power their kitchen appliances were consuming during a day. The users were asked when they thought that is was okay for the energy supplier to use their energy data. Many users answered that it is okay if it benefitted them in some way, mainly in the form of energy savings, better services and the for good cause as e.g. for research. Some users thought that is was not okay if the company used the data for additional sales, while others thought that it is was okay. Some argued that if you choose to have a HEM System then you must accept that one's energy data is being collected.

Discussion

The test user did not expect that the HEM System would increase their feeling of safety at home and over home. There is a risk that the users did consider their early experiences when answering the statement, since they already had tried the HEM System and been subjected to problems. Another explanation could be that the respondents, at the early state of the trial, was not aware of what the HEM System could have contributed with to increase their feeling of safety at the home. The experience study did in fact show that the test users valued three services linked to control aspects as the top five most important ones. It was however also shown that the users trust in the HEM System was rather low. Reasons could be that the test user did get into the trial at an early stage of the development of the HEM System, their trust would probably have been higher if they had not been exposed to problems due to the development of the product.

Most users were shown to have no issues with an energy company collecting their energy data as long as the data was used in a proper way, but the test users might have more trust in energy companies than the average persons since they all are employed by one.

4.6 Awareness and knowledge

The expectation study showed that many test users stated to be quite well aware of their household electricity use. The test users answered the statement "I know how much electricity in kWh my household consume per year", out of three alternatives, 61% answered "I know", 39% answered "I think I know" and 0% "I don't know". They were also asked about the cost of their monthly electricity bills, quite many consider themselves to have good knowledge, the strength of their conviction was 41% while the strength of their scepticism was 17%. The respondents seem, on the other hand, to find it quite difficult to understand information about their energy use on "My pages" or on the electricity bill. The strength of the respondents' conviction finding it easy to understand the information was 30% while the strength of scepticism was 24%. The survey also showed that the respondents strongly believed that the HEM System would increase their knowledge and insight regarding their energy use. The strength of the respondents' conviction was 78% while the strength of scepticism was 0%.

During the interviews the test users were asked two similar questions regarding their awareness and knowledge about their energy use. The answers turned out to be quite the same. 9 out of 13 test users believed that they by using the HEM System had become more aware of their energy use compared to before the trial. The users stated that they had increased their awareness of what specific appliances at home consume. Many users also stated that they because of the HEM System now reflect more over their energy use than before the trial. One user said:

> "I thought I was aware. I'm much more aware now, those standby and TV sets always switched on all day in the children's room. Before I have reflected when I got the electricity bill and after two harsh winters, it was a bit expensive. Now I am more aware and the trial has helped."

12 out of 17 test users believed that they had increased their knowledge and insight regarding their energy use by using the HEM System. Three test users thought that the increased knowledge was marginal and two did not think they had increased their knowledge at all. Some users stated that they for example learned what a washing machine consume and some had learned consumption patterns for different appliances and some even behavioural patterns of the household. Some users have experienced that they have been able to locate what "matters", what at home that consumes a lot of electricity. Some have, based on their new knowledge, chosen to use or not use some electrical appliances. For example one user said:

> "Well we've had a smart plug on the dryer. I learned that it consumes unnecessarily much even though it is a new dryer. If the weather is nice we do not tumble dry."

Discussion

A goal with the HEM System is to increase the users' awareness and knowledge regarding energy use, this study shows that the system has for filled its purpose. The test users' increased awareness and knowledge are mostly related to what specific appliances at home consume. It was shown that detailed feedback, the electricity consumption of specific electrical appliances, has helped the users to make decisions whether to use or not use the appliances (also shown in a study by Hargreaves et al (2010) see sub-chapter 2.4).

4.7 Motivation and behavioural change

Motivation

The test users were asked during the interviews what would motivate them to save energy. Out of six specified scenarios (see Table 3) the respondents considered cost savings to motivate them the most to save energy. Coaching from E.ON was the scenario that they believe would motivate them the least, some of them stated that this is because they already have good knowledge about various energy issues. Many users claimed that a competition would not motivate them, but then they came to think of the Saving Mode challenge and many realized that it did motivate them.

Table 3. How much different scenarios could motivate energy saving.

Scenario	*Not at all*	*To some degree*	*Rather much*	*Very much*	*Likert scale*
Cost savings	0 (0.0%)	3 (16.7%)	11 (61.1%)	4 (22.2%)	52.8%/ -8.3%
Community comparison	3 (16.7%)	2 (11.1%)	11 (61.1%)	2 (11.1%)	41.7%/ -22.2%
Comparison with the own previous energy use	0 (0.0%)	10 (55.6%)	6 (33.3%)	2 (11.1%)	27.8%/ -27.8%
Some form of competition	5 (27.8%)	6 (33.3%)	5 (27.8%)	2 (11.1%)	25.0%/ -44.4%
Own goal target	1 (5.6%)	10 (55.6%)	6 (33.3%)	1 (5.6%)	22.2%/ -33.3%
Coaching from E.ON	4 (22.2%)	10 (55.6%)	4 (22.2%)	0 (0.0%)	11.1%/ -50.0%

During the interviews the test users were also asked a few questions about environmental aspects. The vast majority of the test users consider themselves to be environmental friendly but they were doubtful if display of environmental impact would motivate them to save energy. Only two users said that it

would motivate, seven said that it might and seven answered that it would not motivate more. The more positive users stated that one of reasons to save energy is for the environment. One user said:

> "Not everyone is driven by money".

Another user said regarding if display of environmental impact would motivate energy savings:

> "Yes, it might raise my awareness, which in turn could increase the incentive to save energy. I believe maybe it would motivate"

Behavioural change

The expectations survey showed that the test users believed that the HEM System would have an influence on their energy related behaviour, the strength of the respondents conviction was 63% while the strength of their scepticism was 4%. They also considered themselves to be willing to change their energy-related behaviour on recommendation of the HEM System in order to achieve cost savings. The strength of their conviction was 59% while the strength of scepticism was 6%. Some respondents did however pinpoint that they were not willing to do just anything to achieve energy savings or cost savings.

During the interviews the test users were asked whether they due to the HEM System noticed any changes in the way they were using power or heat. Most users responded that they had achieved changes regarding the heat use. Some users said that they had scheduled the heat use and did not therefore need change the thermostats levels as before, and others argue that the temperature regulation worked better and that they therefore now did not change the thermostats levels. One user stated that they were changing the temperature settings more often now since the HEM system made it easier. The study also showed that many users due to the HEM System switched off electrical appliances on standby more often. Some users stated that they had become better at switching off electrical appliances which did not need to be switched on and one user had even started to unplug chargers that the family left in the wall socket. Some users started to discuss energy use at home and were using the HEM System to try to get their children more aware of energy use and the actual cost of it. During the challenge to test Saving Mode a few users made energy-related changes by choosing when to use some appliances according to the time tariffs. One user said regarding change of energy use:

> "Yes I'm more prone to save energy in general. Now I switch off things that do not need to be on. I have also learned which appliances that does not need maintenance power and can be switched off."

Discussion

The motivation to save energy was relatively low looking at all scenarios. This might indicate that the test users are more interested in the HEM System and the technology than the benefits of saving energy. It was shown that users were doubtful if display of environmental impact would motivate them to save energy, but since one of the main reasons for Swedish people to save energy is the environment (SIFO, 2011) it might be good to add this feature for the system to appeal to all future users.

The HEM System did have an impact on the test users' energy-related behaviour, the users have achieved changes both regarding their power and heat use. The changes were both behavioural and related to the HEM System and then mainly to the Schedule. The changes related to the HEM System

will hopefully be lasting as long as the user still have the HEM System, but if the behavioural changes will be permanent needs to be further evaluated.

4.8 Customer value

The user of a HEM system should regarding their energy use experience and generate various benefits from the system, these can essentially be divided into four categories: control, comfort, knowledge and savings. This study shows that the HEM System provides the tools for the users to achieve these benefits and that most of the criteria were fulfilled (see Table 4).

Table 4. Customer values which the HEM System provide.

Energy control Heat: Yes Power: Yes The test users experienced that the HEM System provides better control over their power and heat user, by advantage also by remote control.	*Energy Comfort* Heat: Yes Power: Maybe The test users experienced a better thermal comfort at home. They think that it due to the HEM System is easier to turn on/off electrical appliances at home.
Energy Knowledge Heat: Yes (some users) Power: Yes Most test users have learned what specific electrical appliances at home consume. A few users have stated that they noticed the effect of the heat use on the total energy use.	*Energy Savings* Heat: Likely Power: Yes The HEM System provides the possibility to save heat and power energy foremost by using the Schedule and Saving Mode. How large this savings can become both in terms of energy and money needs to be further evaluated.

4.8.1 Willingness to pay

The test users were during the interviews asked if they would like to keep the HEM System after the trial without having to pay for it, all answered yes without doubt. The test users were also asked if they were willing to pay for the HEM System, 7 out of 18 test users directly answers yes while 8 of 18 answered that it depended on the price or the potential savings that they by using the system could achieve. Two test users said that they were willing to pay for the heat side, but not for the power side. One test user was not willing to pay for the HEM System.

Some users would preferably like to pay upfront while others would like to pay a monthly fee. A few users said that they were willing to pay a monthly fee if it would mean that after a few years had paid off the system and thereby in the end own the HEM System themselves.

5 Concluding discussion

The study results from both the expectation and the experience evaluations were overall expected. The test users had in general high expectations on the HEM System and the system met most of them. It has been proven that the HEM System provides the tools for the users to monitor and control their energy use. The test users did obtain new insights and knowledge regarding energy use and they made some changes in the way that they were using energy. An unexpected result was that services that can assist users in achieving energy savings were ranked of rather low importance compared to other services. An explanation could be that the test users were more interested in HEM technology than in the energy saving purpose. Another explanation could be that many users considered themselves to

have good energy-related knowledge and thereby not seeing e.g. energy saving coach and tips on saving measure as interesting services.

The trial

The R&D trial started when the HEM System was not fully developed and it had basically never been tested before. Due to the early stage of development the test users were subjected to many problems. The impression is that most test users felt that they during the trial had to spend too much effort to get the HEM System to work properly. The efforts probable also seemed larger since they did not know if it would lead to benefits in form of energy savings or if they might had to reinforce with more efforts. New technology can often be perceived unreliable and to entrust the control over power and heat use at home to a technical system may feel insecure. High expectations of the development progress of the HEM system before the trial might also have affected their feelings, some users mentioned, during the interviews, that they had expected a more developed HEM System to start with. It also seems that a negative perception of the system has been exacerbated by the fact that the test users have seen on the Facebook-group that other test users had problems even though it did not affected them. These aspects of the test users' feelings are presumably telling that their perception of the system would have been better if the system was more developed to begin with. One must also take into consideration that the test users were friendly users. These are important factors to take in consideration before taking the HEM System to the market.

Weakness of the trial

All test users were friendly users and employed by E.ON, this suggest that they before the trial probably had better knowledge of energy-related aspects than an average person. Their approach to energy issues and E.ON as a utility may have slanted their responses. It might therefore be inaccurate to generalise the results on a "normal" test user not being in the same position in relation to E.ON and energy issues.

The expectation survey was sent to the test users when they had already installed the HEM System. The users were encouraged to disregard the first test period and respond honestly and critically about the issues. Their early experience of the HEM System may have had an impact on their attitudes and thus influenced their replies. Many test users had technical problems during the first period of the trial which was noticed in the free comments of the survey.

Further studies and development

It would be interesting to further evaluate if the test users energy-related changes, both the behavioural and the ones connected to HEM System, are consistent and how they would use the HEM System in the future e.g. after one year. It would also be interesting to evaluate how the average person would perceive and use the HEM System, and evaluate which incentives the average person would have for using it. The SIFO-survey showed that Swedish peoples' main incentives for energy savings are cost savings and environmental aspects. One can then question if the average person will use a function like Saving Mode if the energy and/or cost savings are too small. Another question is whether people can learn to adapt to a function like Saving Mode. This study indicates that the savings need to be larger and that people have difficulties to change their daily routines for the purpose of energy savings. The comfort was also shown to be more important than energy savings. The energy supplier can probably, however, motivate its customers to change their energy use by making larger price differences between low and high tariffs.

Transparent and frequent energy feedback is an important factor to achieve energy-related behavioural changes, but studies have also shown that energy feedback displays have an enduring impact even if only used for a short periods. One can, however, question if energy use is interesting enough for further users to continuously use the HEM System and thereby being subjected to the feedback. The HEM System does provide the opportunity for the users to make settings and then let the system co-control their energy use, which it positive since this should generate larger savings than if the system was not used at all. The question is whether the energy savings could have been larger if the HEM System was used more frequently and how the energy supplier can motivate the users to use the system. The motivation to use apps could probably decrease if the user begins to question the benefits of the HEM System. Is it to achieve energy savings or to increase the comfort? Perhaps both, but can the two go hand in hand? These aspects need to be further evaluated.

The HEM System generates benefits for both its users and for the energy supplier. The users were given the opportunity to control and reduce their energy consumption and to get better knowledge about their energy use. The energy supplier can through the HEM System get better knowledge of the customers' energy use and they have an opportunity to influence the energy demand. These aspects suggest that further development of HEM Systems is an important issue.

6 Conclusions

The findings can be summarized as follow:

Expectations
The test user had in general high expectations on the HEM System. They expected, among other things, that they would: save energy, experience a better thermal comfort, increase their energy-related knowledge and get better control over their energy use. It was shown that HEM System met most of the test users' expectations.

Overall satisfaction
Most test users were overall satisfied with the HEM System, this despite the many complications and a lot of efforts by users to get the system to work properly. All test users would like to keep the HEM system in the future and many were also willing to pay for the HEM System.

The HEM System features
The test users were satisfied with the amount of services and features that were included in the HEM System. They considered that most of them were technically working well, but they had some opinions on improvements to make the HEM System even more user-friendly.

Heat control
Control and monitoring of the heat use was shown to very valuable to the test users, and most of them were experiencing a better thermal comfort at home due to the HEM System.

Saving Mode – load demand
Saving Mode has been proven to work technically, but though according to the test user good for some electrical appliances and not as good for others. It was also shown that it was difficult for many test users to change their daily routines for the benefits of energy savings.

Energy savings
The HEM System has been proven to provide the tools for the users to achieve energy savings, but how large the energy savings can become needs to be further evaluated.

Knowledge
About 70% of the test users state that they increased their knowledge regarding their energy use by using the HEM System. The users' increased knowledge was foremost related to what specific electrical appliances at home consume.

Behavioural change
Most test users have made some energy-related changes of how they use power or heat or both. The changes made were both behavioural and HEM System related. The system related changes will hopefully be consistent as long as the users keep the HEM System but whether the behavioural changes will be consistent needs to be further evaluated.

More control
The test users' ability to monitor and control their home has increased. The HEM System has also provided the ability to monitor and control their home by remote.

Downside
The test users' trust in the HEM System is considered to be low, 6.2 on a scale of one to ten. The low trust is mainly related to technical problems due to the development of the system. It was also shown that the users' motivation to use the HEM System decreased since: the system was not measuring everything, the measures did not match the invoice, the electricity prices were not real and components were sometimes malfunctioning.

Customer value and their own benefits
The HEM System generates four energy-related customer values: control, knowledge, comfort and savings. The test users were shown to value control over power and heat use as most valuable. The test users found their own way to manage the system and many have found their own specific benefits, some examples are:

"Now I do not need to run down to the laundry room to check if the laundry is done"

"Now I check every day if the electric bike is charging and if it has finished charging"

"Now when I arrive at work I can check that the children have switched off everything at home"

"I try to make my son aware that his computer uses a lot of power"

"Now I've got rid of a lot of standby"

Further development
There are many opportunities for further development of the HEM System, some are; providing more interaction and feedback from the system e.g. regarding installation processes and newly applied settings, adding push notices e.g. when electricity prices are high/low and when the energy use is higher than normal.

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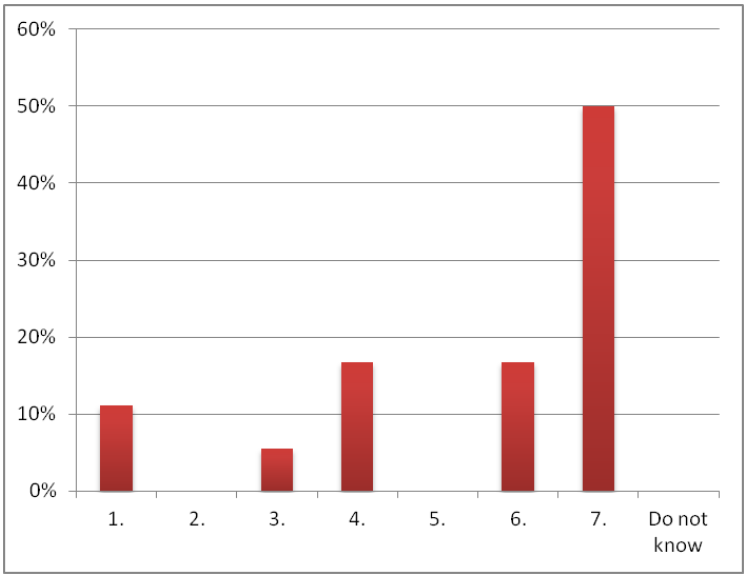
Appendix A

Habits and Awareness

1. I have experience of using smartphones.

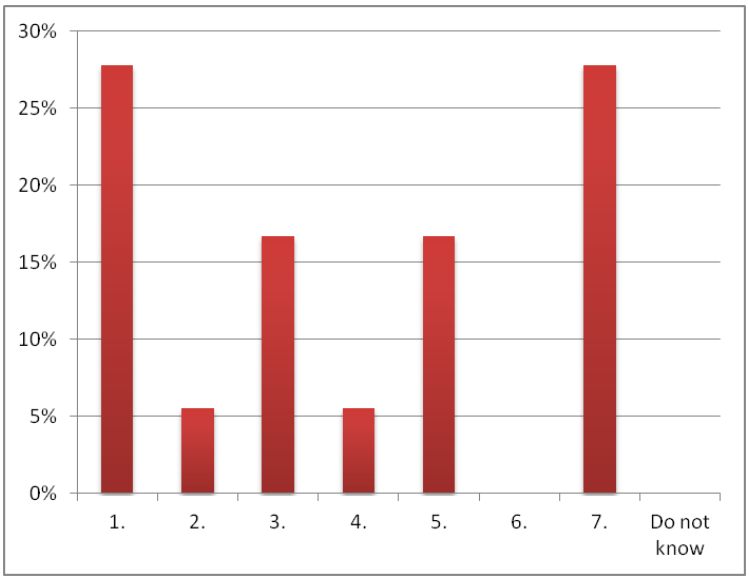


Response rate: 18/18

1. Disagree	2	11.1%
2.	0	0.0%
3.	1	5.6%
4.	3	16.7%
5.	0	0.0%
6.	3	16.7%
7. Strongly agree	9	50.0%
Do not know	0	0.0%

Average: 5.4
Likert scale: 61.1%/ -13.0%

2. I had experience of using tablets before I got to borrow an iPad of E.ON.

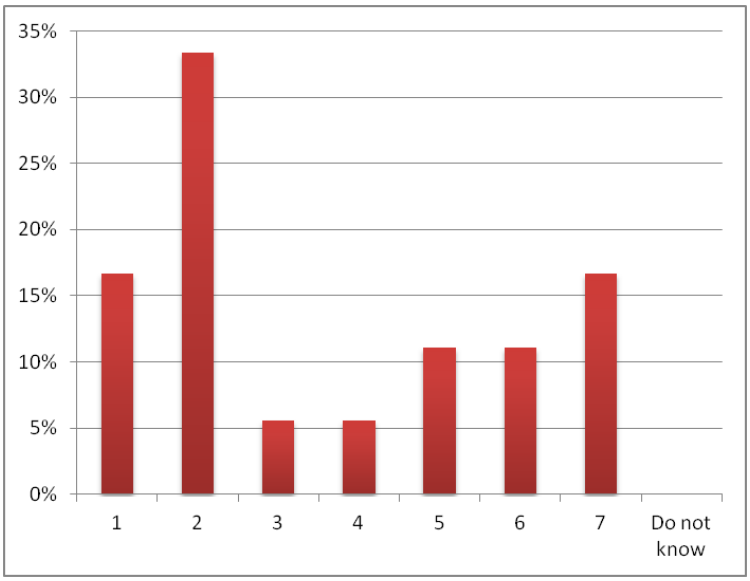


Response rate: 18/18

1. Disagree	5	27.8%
2.	1	5.6%
3.	3	16.7%
4.	1	5.6%
5.	3	16.7%
6.	0	0.0%
7. Strongly agree	5	27.8%
Do not know	0	0.0%

Average: 3.9
Likert scale: 33.3%/ -37.0%

3. Before I installed the Smart Home solution I used remote switches or timers to some electrical equipment at home.

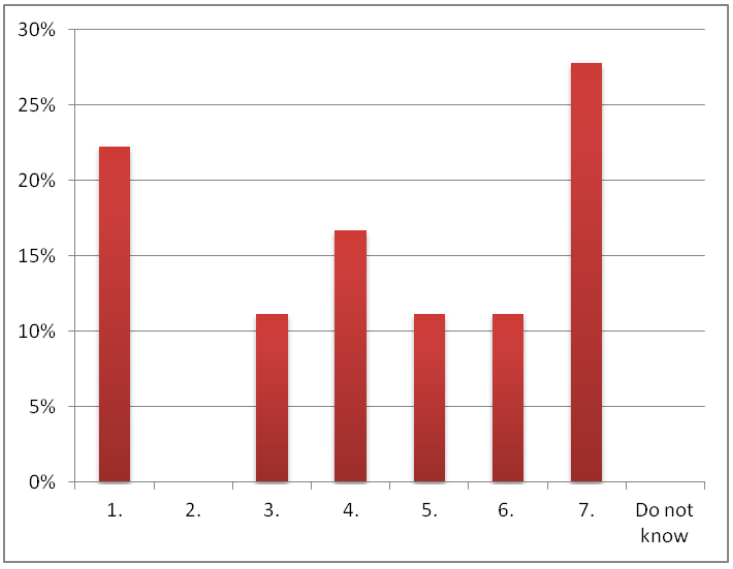


Response rate: 18/18

1. Disagree	3	16.7%
2.	6	33.3%
3.	1	5.6%
4.	1	5.6%
5.	2	11.1%
6.	2	11.1%
7. Strongly agree	3	16.7%
Do not know	0	0.0%

Average: 3.6
Likert scale: 27.8%/ -40.7%

4. I often manually changed the level of the element thermostats, before I installed HEM System.



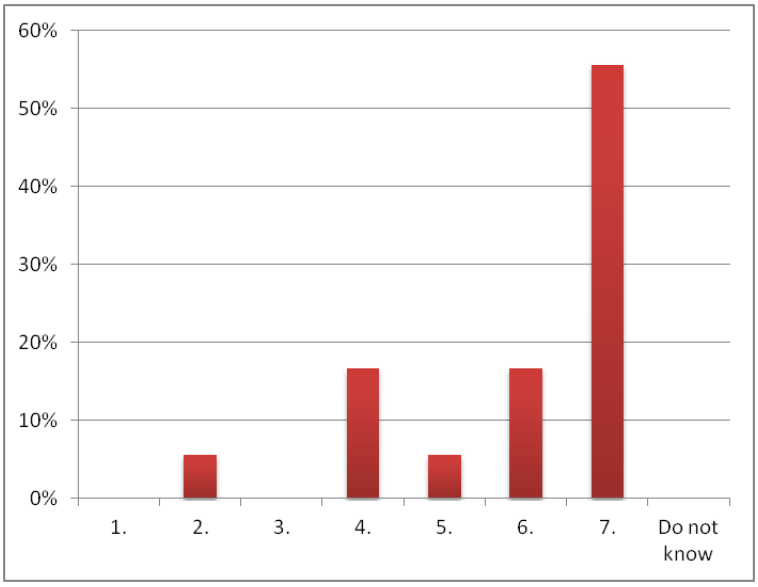
Response rate: 18/18

1. Disagree	4	22.2%
2.	0	0.0%
3.	2	11.1%
4.	3	16.7%
5.	2	11.1%
6.	2	11.1%
7. Strongly agree	5	27.8%
Do not know	0	0.0%

Average: 4.4
Likert scale: 38.9%/ -25.9%

One of the respondents who did not agree with the statement have underfloor heating and thereby no element thermostats. Another respondent strongly agreed to the statement but does not change the thermostats' levels but often the boiler supply water temperature.

15. I expect to save energy by using the HEM System.



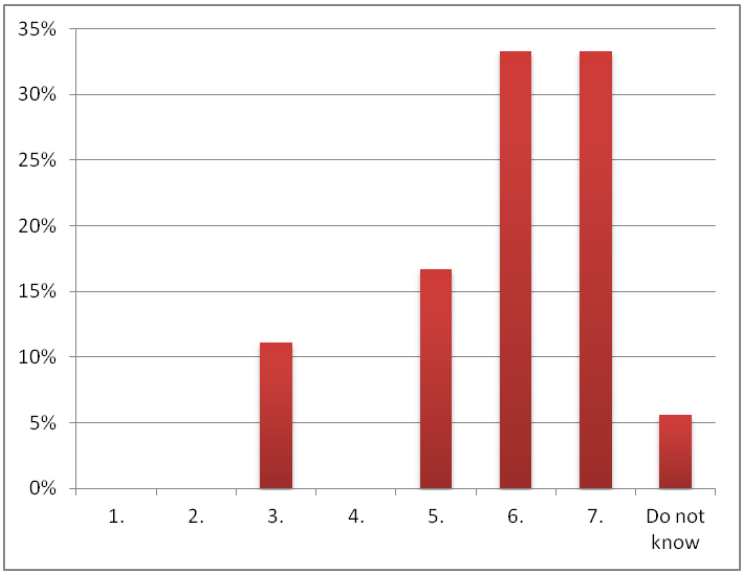
Response rate: 18/18

1. Disagree	0	0.0%
2.	1	5.6%
3.	0	0.0%
4.	3	16.7%
5.	1	5.6%
6.	3	16.7%
7. Strongly agree	10	55.6%
Do not know	0	0.0%

Average: 5.9
Likert scale: 68.5%/ -3.7%

Comment from a respondent: "At least shed light on how behavioural changes can help save energy."

16. I expect that the Smart Home solution will generate an increased thermal heat comfort at home.



Response rate: 18/18

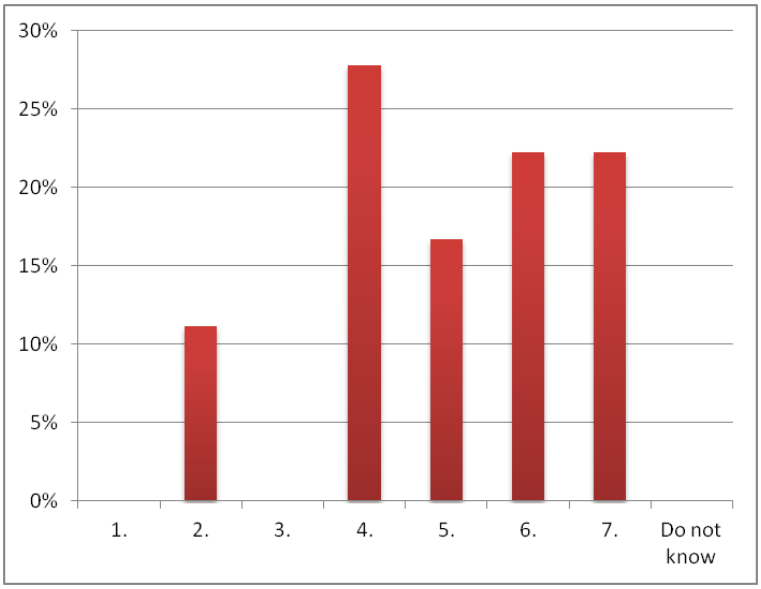
1. Disagree	0	0.0%
2.	0	0.0%
3.	2	11.1%
4.	0	0.0%
5.	3	16.7%
6.	6	33.3%
7. Strongly agree	6	33.3%
Do not know	1	5.6%

Average: 5.8
Likert scale: 61.1%/ -3.7%

One of the respondents have commented that the household does not use regular radiators as heating source and there by choosing "Do not know".

Comment from a respondent: "As the temperature swing a lot in our house, depending on outdoor temperature, wind and sun, we expect a more even indoor temperature."

17. I think that it is important to be able to check that all unnecessary electrical equipment is turned off before leaving home or going to bed.



Response rate: 18/18

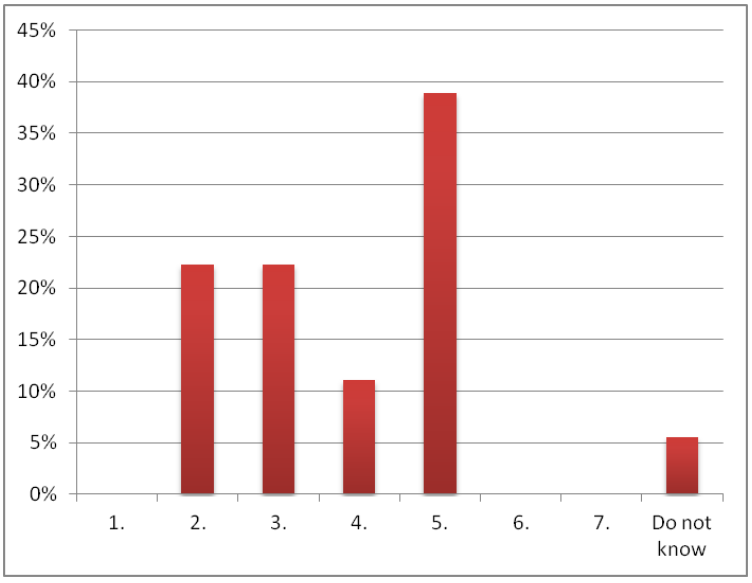
1. Disagree	0	0.0%
2.	2	11.1%
3.	0	0.0%
4.	5	27.8%
5.	3	16.7%
6.	4	22.2%
7. Strongly agree	4	22.2%
Do not know	0	0.0%

Average: 5.1
Likert scale: 42.6%/ -7.4%

Comments from respondents: "I don't want to control anything before going to bed. It should just be that way..."

"Imagine how nice it would be to be able to control if the iron or the stove is turned off when you left home and you can't remember if you really turned it off."

18. I believe that Smart Home solution will increase the family's feeling of safety at home.



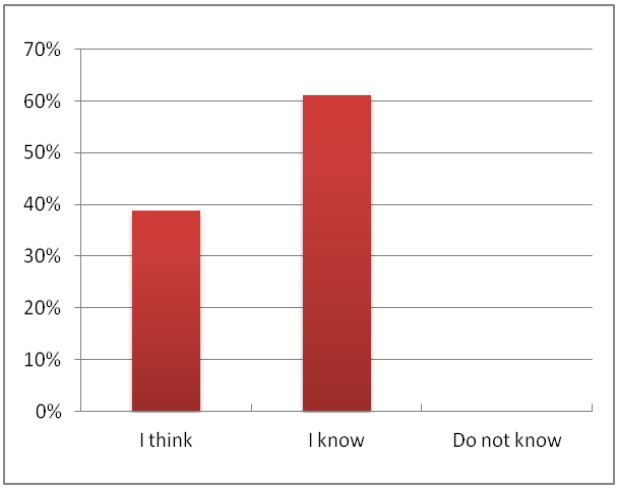
Response rate: 18/18

1. Disagree	0	0.0%
2.	4	22.2%
3.	4	22.2%
4.	2	11.1%
5.	7	38.9%
6.	0	0.0%
7. Strongly agree	0	0.0%
Do not know	1	5.6%

Average: 3.7
Likert scale: 13.0%/ -22.2%

Comment from a respondent: "So far it has been the opposite effect, but it would be great if it could in the long run"

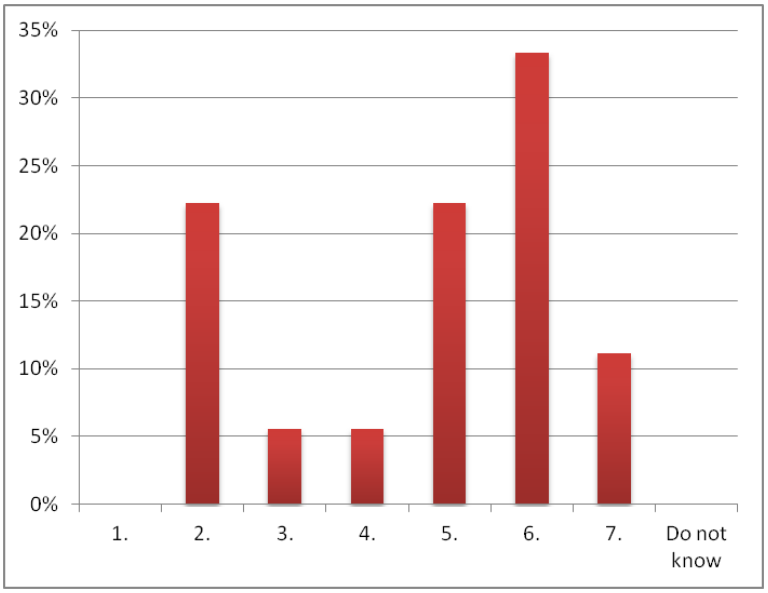
23. I think / I know that my household consume _____ kWh of electricity per year.



Response rate: 18/18

I think	7	38.9%
I know	11	61.1%
Do not know	0	0.0%

25. I roughly know how much electricity, calculated in SEK, that the household consume each month.

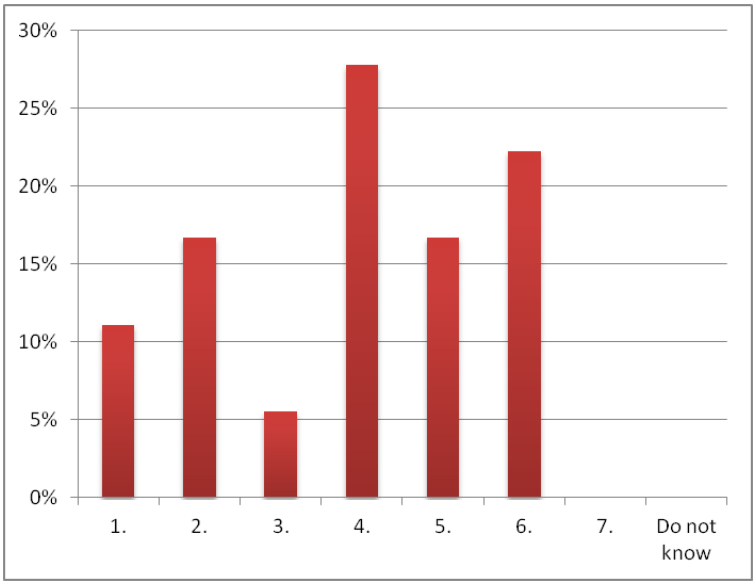


Response rate: 18/18

1. Disagree	0	0.0%
2.	4	22.2%
3.	1	5.6%
4.	1	5.6%
5.	4	22.2%
6.	6	33.3%
7. Strongly agree	2	11.1%
Do not know	0	0.0%

Average: 4.7
Likert scale: 40.7%/ -16.7%

26. I believe that my household consumes a lot more energy than comparable households.

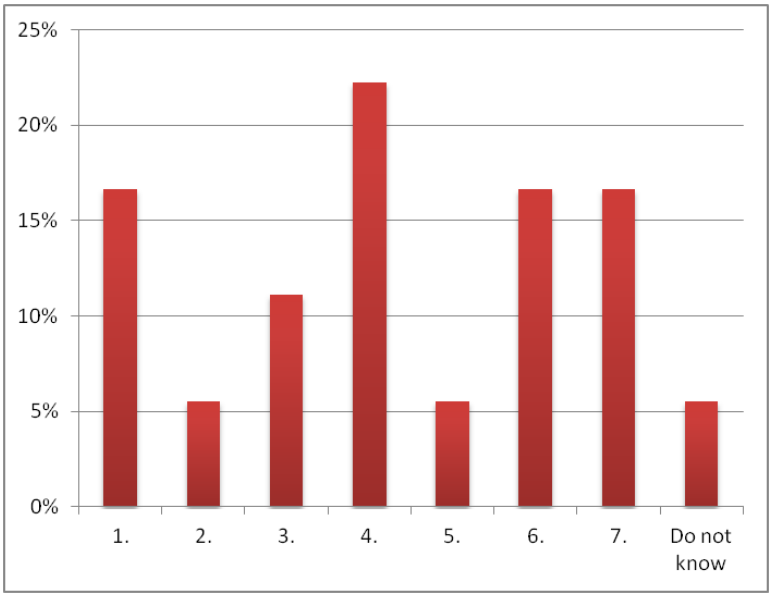


Response rate: 18/18

1. Disagree	2	11.1%
2.	3	16.7%
3.	1	5.6%
4.	5	27.8%
5.	3	16.7%
6.	4	22.2%
7. Strongly agree	0	0.0%
Do not know	0	0.0%

Average: 3.9
Likert scale: 20.4%/ -24.1%

27. I think it is easy to understand information about my electricity consumption on "My pages" or electric bill.



Response rate: 18/18 (100%)

1. Disagree	3	16.7%
2.	1	5.6%
3.	2	11.1%
4.	4	22.2%
5.	1	5.6%
6.	3	16.7%
7. Strongly agree	3	16.7%
Do not know	1	5.6%

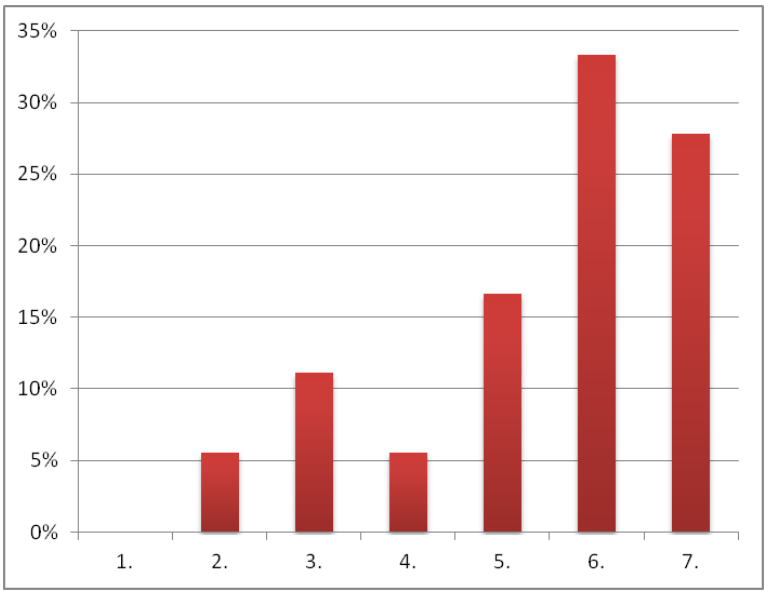
Average: 4.2
Likert scale: 29.6%/ -24.1%

Comments from respondents: "It's only consumption that shows on a monthly basis, that is easy to understand, but there's not much "more" to read?"

"Do not usually get my minds into this fact. I expect a certain amount on an annual basis and as long as it does not stick out I'll pay without further consideration."

Design aspects

12. I had high expectations on the design and appearance of the application.

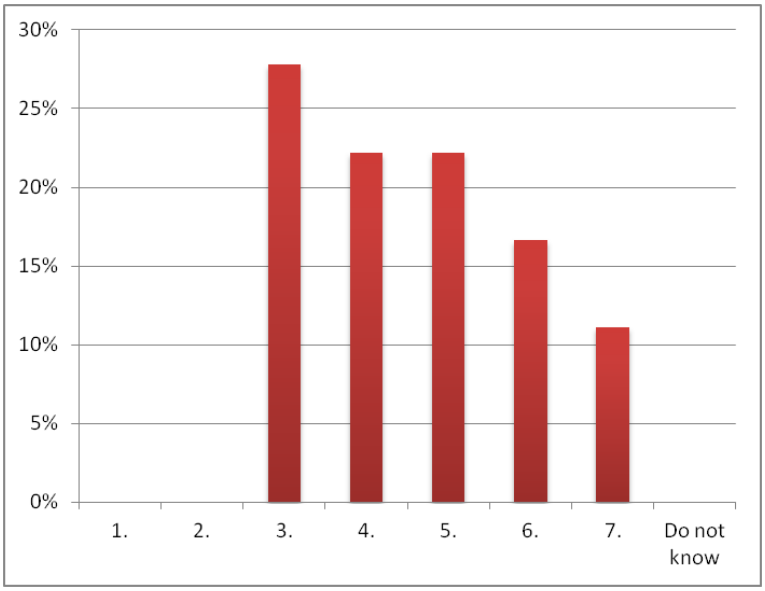


Response rate: 18/18

1. Disagree	0	0.0%
2.	1	5.6%
3.	2	11.1%
4.	1	5.6%
5.	3	16.7%
6.	6	33.3%
7. Strongly agree	5	27.8%
Do not know	0	0.0%

Average: 5.4
Likert scale: 55.6%/ -7.4%

13. For me it is more important with clear and transparent information than an attractive design.



Response rate: 18/18

1. Disagree	0	0.0%
2.	0	0.0%
3.	5	27.8%
4.	4	22.2%
5.	4	22.2%
6.	3	16.7%
7. Strongly agree	2	11.1%
Do not know	0	0.0%

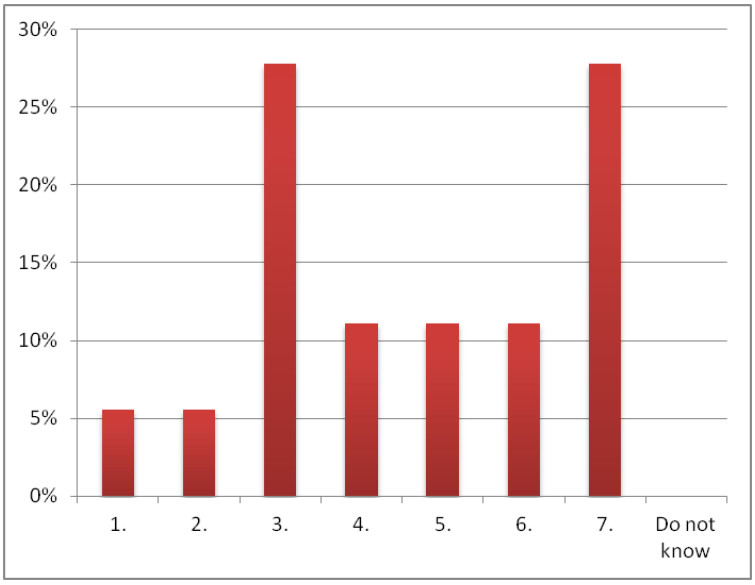
Average: 4.6
Likert scale: 29.6%/ -9.3%

Comments from respondents: “The question is contradictory. Attractive design does not stand in relation to transparency of information - as evidenced by among other e.g. Apple. Both aspects are important and they are not linked to each other.”

“Both are as important”

“Preferably in a table than in bubbles and stuff”

14. I had high expectations of the design of smart plugs, thermostats, gateway and alarm components.



Response rate: 18/18

1. Disagree	1	5.6%
2.	1	5.6%
3.	5	27.8%
4.	2	11.1%
5.	2	11.1%
6.	2	11.1%
7. Strongly agree	5	27.8%
Do not know	0	0.0%

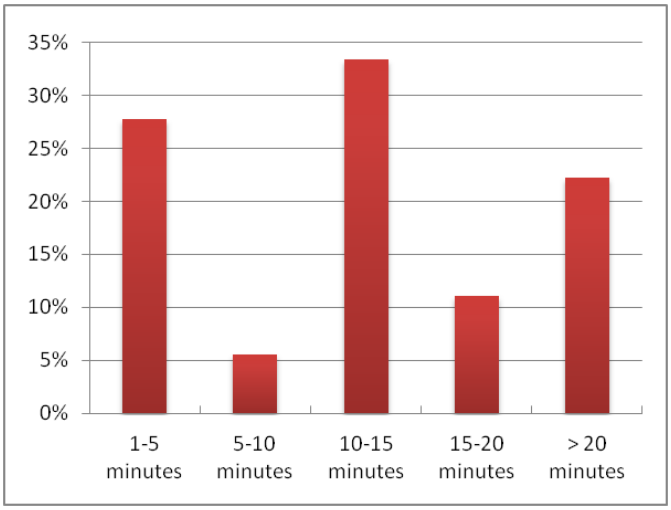
Average: 4.6
Likert scale: 38.9%/ -18.5%

Women care more about the design of components than the men. 57% of the female respondents strongly agreed to the statement verses 9% of the male respondents.

Comment from a male respondent: "We must do something about the design of "everything" that is visible. For example, the Smart Plugs are horribly ugly and I will not have them in my home after the test period. Smaller or integrated into the wall sockets."

Installation

6. How many minutes were you willing to spend on installation of the application on your iPad?



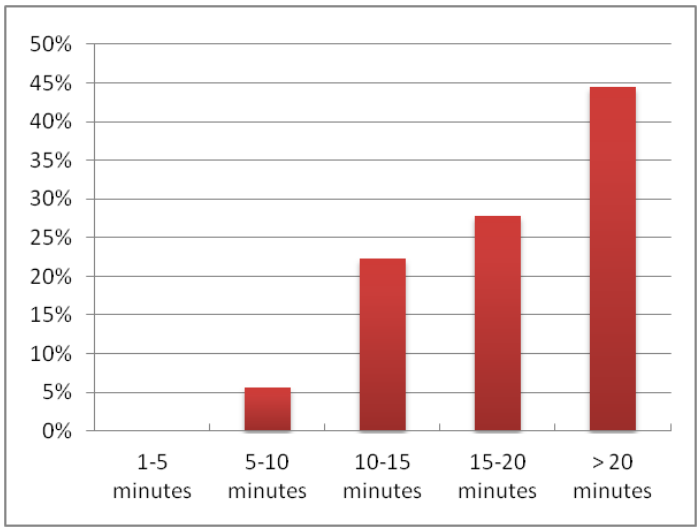
Response rate: 18/18

1-5 minutes	5	27.8%
5-10 minutes	1	5.6%
10-15 minutes	6	33.3%
15-20 minutes	2	11.1%
> 20 minutes	4	22.2%

Average: 10-15 minutes

Comment from a respondent: “Up to 30 minutes. When it is the new stuff it often takes longer than you think, but it should not take too long...”

7. How many minutes were you willing to spend on the installation of 10 smart plugs at home?

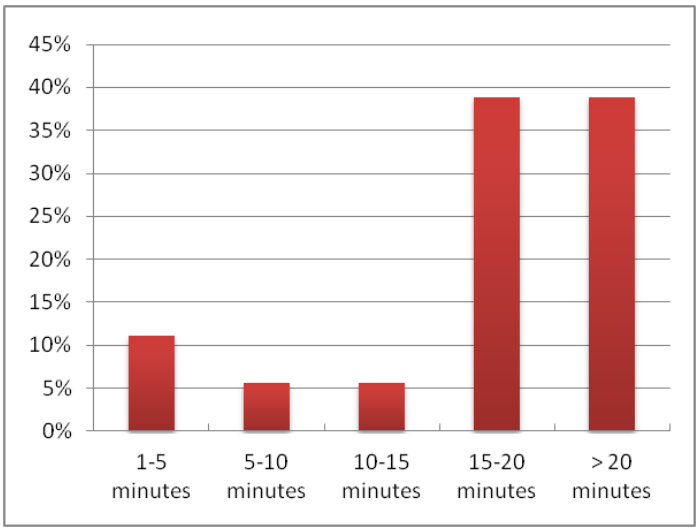


Response rate: 18/18

1-5 minutes	0	0.0%
5-10 minutes	1	5.6%
10-15 minutes	4	22.2%
15-20 minutes	5	27.8%
> 20 minutes	8	44.4%

Average: 15-20 minutes

8. How many minutes were you willing to spend on the physical installation of 4 thermostats at home?

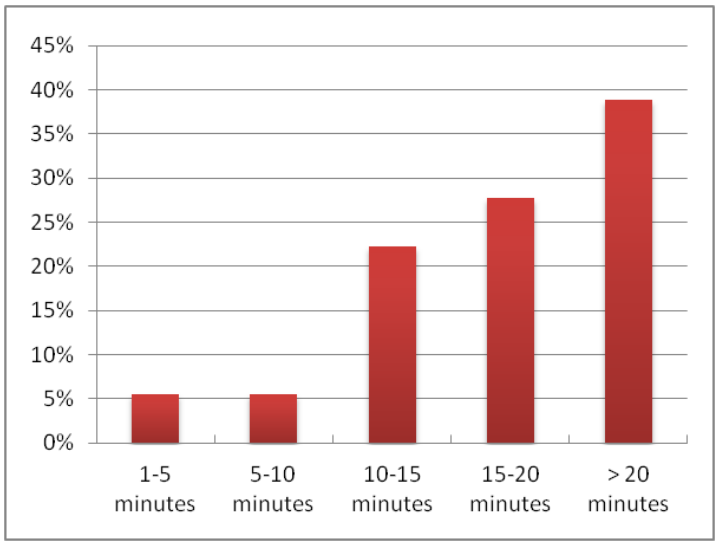


Response rate: 18/18

1-5 minutes	2	11.1%
5-10 minutes	1	5.6%
10-15 minutes	1	5.6%
15-20 minutes	7	38.9%
> 20 minutes	7	38.9%

Average: 15-20 minutes

9. How many minutes were you willing to spend on the physical installation of alarm components at home?

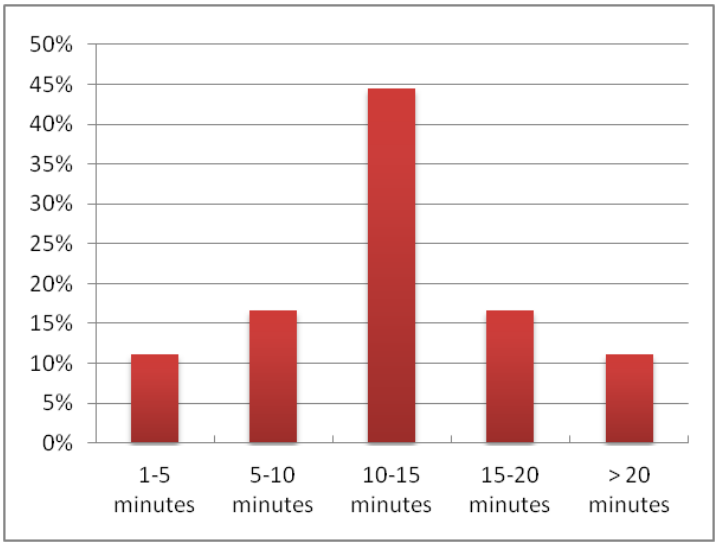


Response rate: 18/18

1-5 minutes	1	5.6%
5-10 minutes	1	5.6%
10-15 minutes	4	22.2%
15-20 minutes	5	27.8%
> 20 minutes	7	38.9%

Average: 15-20 minutes

10. How many minutes were you willing to spend on the installation of smart plugs and thermostats in the iPad-application?



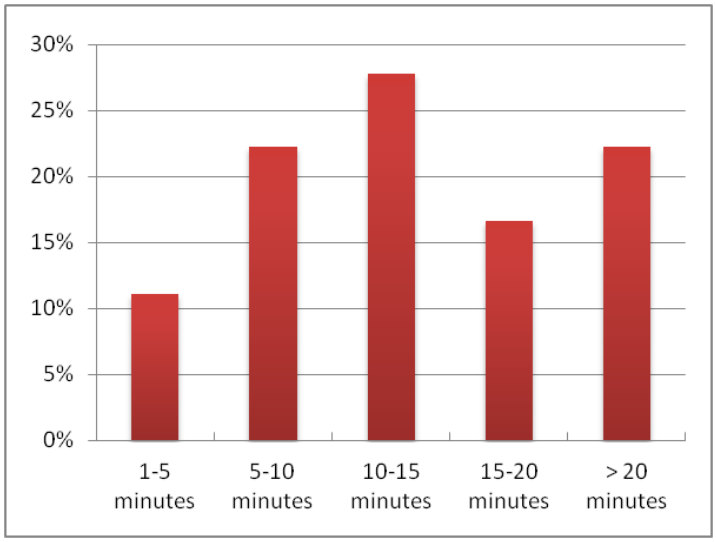
Response rate: 18/18

1-5 minutes	2	11.1%
5-10 minutes	3	16.7%
10-15 minutes	8	44.4%
15-20 minutes	3	16.7%
> 20 minutes	2	11.1%

Average: 10-15 minutes

Comments from a respondent: "I'm a plug and play person. It should be simple and I only have some patience with hassles."

11. How many minutes were you willing to spend on learning how to use the application?



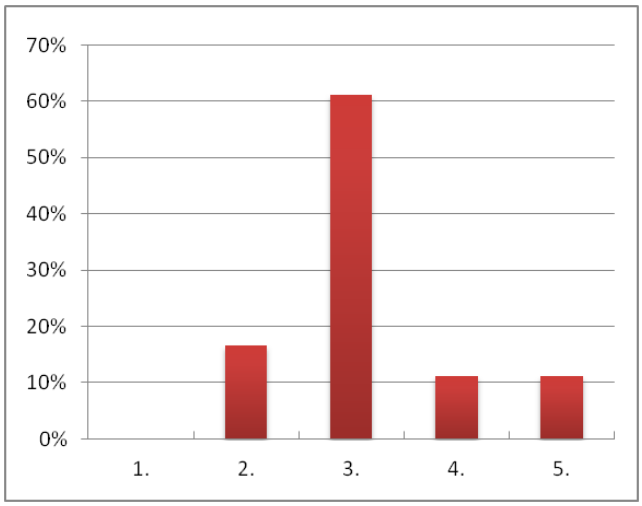
Response rate: 18/18

1-5 minutes	2	11.1%
5-10 minutes	4	22.2%
10-15 minutes	5	27.8%
15-20 minutes	3	16.7%
> 20 minutes	4	22.2%

Average: 15-20 minutes

Using the HEM System

28. I think that I will use the iPad application:



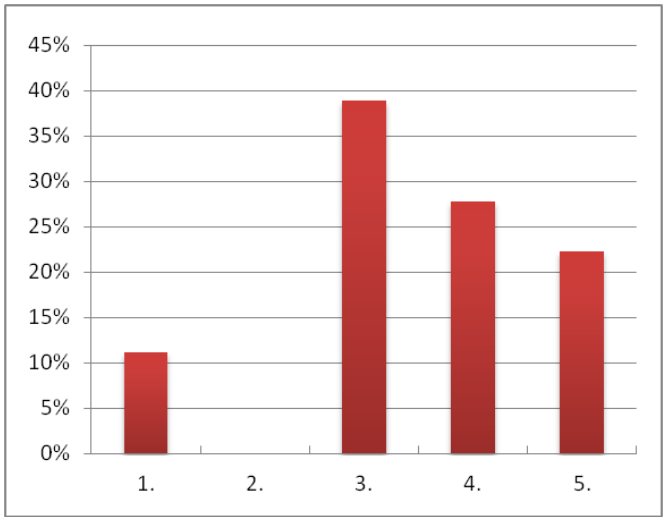
Response rate: 18/18

1. Less often than once / week	0	0.0%
2. Once / week	3	16.7%
3. Several times / week	11	61.1%
4. Once / day	2	11.1%
5. Several times / day	2	11.1%

Average: 3.1

Comment from a respondent: “More than once a week during the start up but later on about once a week.”

29. I think that I will use the iPhone application:



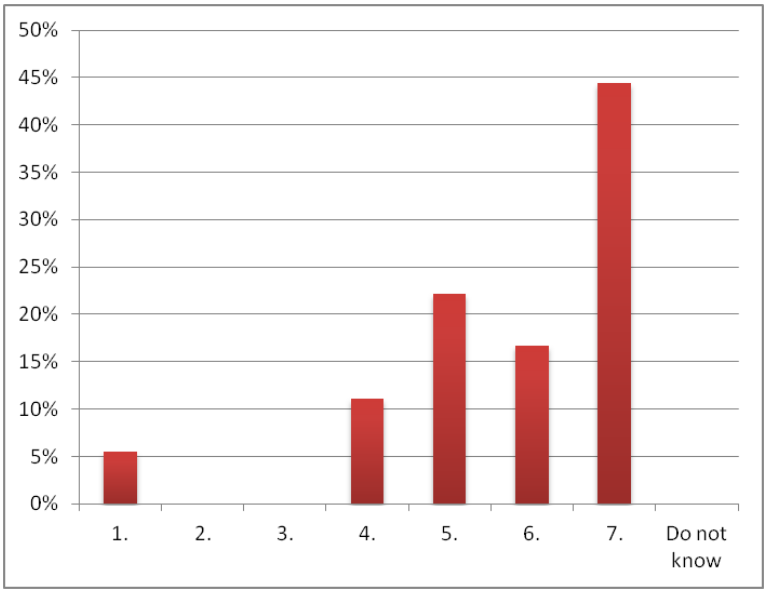
Response rate: 18/18

1. Less often than once / week	2	11.1%
2. Once / week	0	0.0%
3. Several times / week	7	38.9%
4. Once / day	5	27.8%
5. Several times / day	4	22.2%

Average: 3.5

Comments from a respondent: " It is difficult to know but I think it will be used more often than the iPad app."

19. I expected to be able to see the household's energy consumption calculated in Swedish krona (SEK).

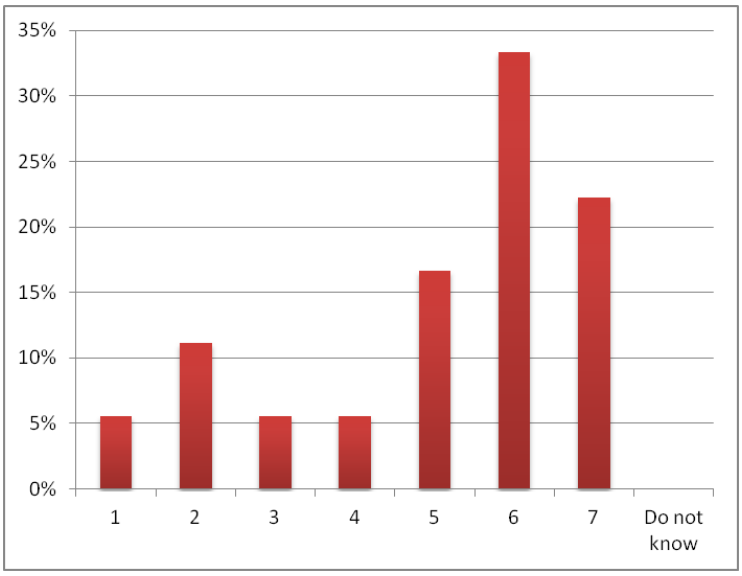


Response rate: 18/18

1. Disagree	1	5.6%
2.	0	0.0%
3.	0	0.0%
4.	2	11.1%
5.	4	22.2%
6.	3	16.7%
7. Strongly agree	8	44.4%
Do not know	0	0.0%

Average: 5.7
Likert scale: 63.0%/ -5.6%

20. I expected to be able to read possible energy savings calculated in Swedish krona (SEK).

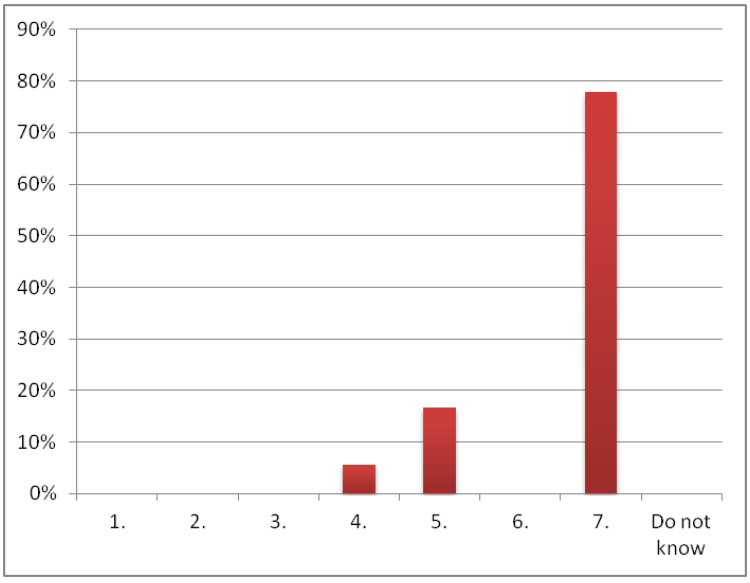


Response rate: 18/18

1. Disagree	1	5.6%
2.	2	11.1%
3.	1	5.6%
4.	1	5.6%
5.	3	16.7%
6.	6	33.3%
7. Strongly agree	4	22.2%
Do not know	0	0.0%

Average: 5.2
Likert scale: 50.0%/ -14.8%

21. I expected to be able to read the household energy consumption in real time.

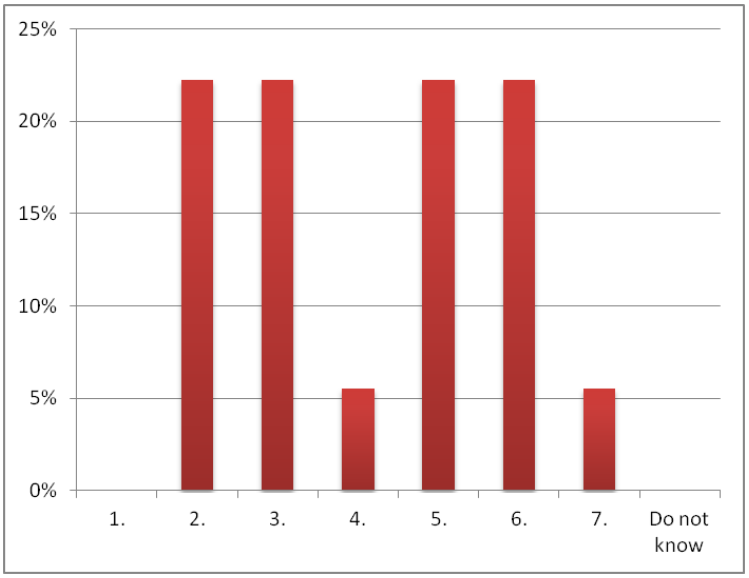


Response rate: 18/18

1. Disagree	0	0.0%
2.	0	0.0%
3.	0	0.0%
4.	1	5.6%
5.	3	16.7%
6.	0	0.0%
7. Strongly agree	14	77.8%
Do not know	0	0.0%

Average: 6.5
Likert scale: 83.3%/ -0.0%

22. I expected to be able to read the environmental impact of the household.



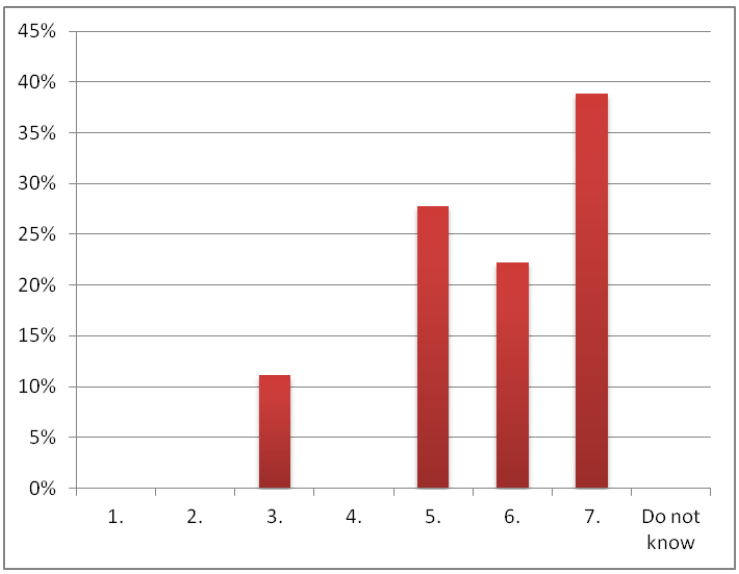
Response rate: 18/18

1. Disagree	0	0.0%
2.	4	22.2%
3.	4	22.2%
4.	1	5.6%
5.	4	22.2%
6.	4	22.2%
7. Strongly agree	1	5.6%
Do not know	0	0.0%

Average: 4.2
Likert scale: 27.8%/ -22.2%

Behavioural change

30. I think that the HEM System will have an impact on my energy-related behaviour.



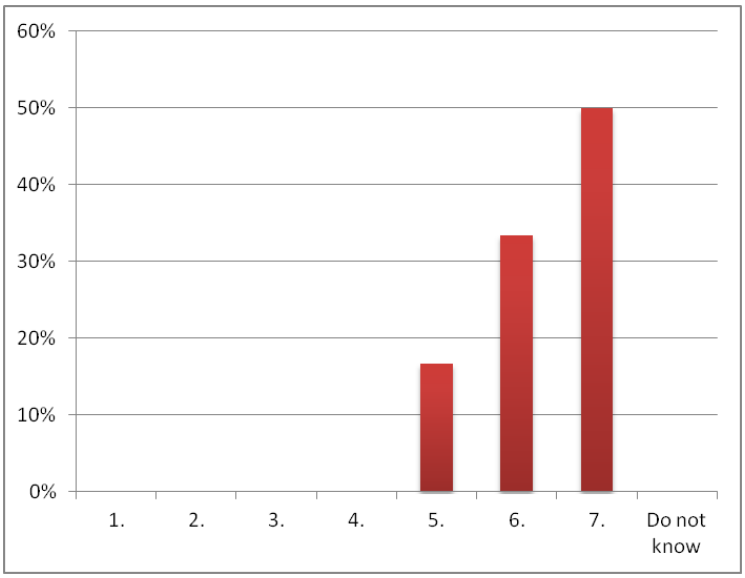
Response rate: 18/18

1. Disagree	0	0.0%
2.	0	0.0%
3.	2	11.1%
4.	0	0.0%
5.	5	27.8%
6.	4	22.2%
7. Strongly agree	7	38.9%
Do not know	0	0.0%

Average: 5.8
Likert scale: 63.0%/ -3.7%

Comment from a respondent: “I think I will be more aware of kWh in general and what specific things really consume.”

31. I think the HEM System will provide increased knowledge and insight regarding the household's energy use.

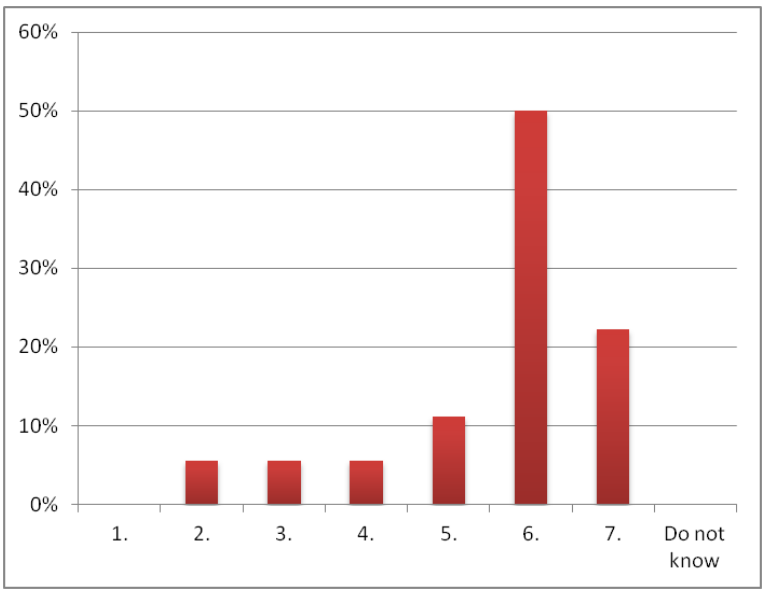


Response rate: 18/18

1. Disagree	0	0.0%
2.	0	0.0%
3.	0	0.0%
4.	0	0.0%
5.	3	16.7%
6.	6	33.3%
7. Strongly agree	9	50.0%
Do not know	0	0.0%

Average: 6.3
Likert scale: 77.8%/ -0.0%

32. I am willing, on recommendation of the HEM System, to change my energy-related behaviour to achieve energy savings (e.g. choose not to run the dishwasher when electricity prices are high).



Response rate: 18/18

1. Disagree	0	0.0%
2.	1	5.6%
3.	1	5.6%
4.	1	5.6%
5.	2	11.1%
6.	9	50.0%
7. Strongly agree	4	22.2%
Do not know	0	0.0%

Average: 5.6
Likert scale: 59.3%/ -5.6%

The statement is unfortunately misleading, since it is refers to achieved savings by running the dishwasher at another time. This can of course not result in energy savings but in money savings. But since 71% agree to the statement one could suspect that respondents understood the meaning of it.

Some respondents have pointed that they are not willing to do just everything to achieve energy savings, which could be an explanation for some scattered result. “Comfort and self-determination is more important.” One of the respondents believe that savings due to running the dishwasher at another time only generates a saving of about 20 öre thus not making it worth changing the behaviour.

HEM services

Service	Not at all important (1)	Not important (2)	Neither nor (3)	Important (4)	Very important (5)	Average	Likert scale
Display real time electricity use	0 (0.0%)	0 (0.0%)	0 (0.0%)	7 (38.9%)	11 (61.1%)	4.6	80.6%/ -0.0%
Display last month electricity use	0 (0.0%)	0 (0.0%)	0 (0.0%)	7 (38.9%)	11 (61.1%)	4.6	80.6%/ -0.0%
Setting temperature	0 (0.0%)	0 (0.0%)	0 (0.0%)	8 (44.4%)	10 (55.6%)	4.6	77.8%/ -0.0%
Setting the Temperature for Home / Away / Asleep / Vacation	0 (0.0%)	0 (0.0%)	0 (0.0%)	8 (44.4%)	10 (55.6%)	4.6	77.8%/ -0.0%
Remote control	0 (0.0%)	0 (0.0%)	1 (5.6%)	7 (38.9%)	10 (55.6%)	4.5	75.0%/ -0.0%
Display last year electricity use	0 (0.0%)	1 (5.6%)	0 (0.0%)	7 (38.9%)	10 (55.6%)	4.4	75.0%/ -2.8%
Overview and control of electrical equipment	0 (0.0%)	0 (0.0%)	0 (0.0%)	10 (55.6%)	8 (44.4%)	4.4	72.2%/ -0.0%
On/Off electrical equipment	0 (0.0%)	0 (0.0%)	1 (5.6%)	8 (44.4%)	9 (50.0%)	4.4	72.2%/ -0.0%
Display last week electricity use	1 (5.6%)	0 (0.0%)	0 (0.0%)	8 (44.4%)	9 (50.0%)	4.3	72.2%/ -5.6%
Comparative electricity use to former periods	0 (0.0%)	0 (0.0%)	3 (16.7%)	7 (38.9%)	8 (44.4%)	4.3	63.9%/ -0.0%
Scheduling On/Off	0 (0.0%)	0 (0.0%)	2 (11.1%)	10 (55.6%)	6 (33.3%)	4.2	61.1%/ -0.0%
Home / Away / Asleep / Vacation-function	0 (0.0%)	0 (0.0%)	3 (16.7%)	10 (55.6%)	5 (27.8%)	4.1	55.6%/ -0.0%
Display possible energy savings	0 (0.0%)	0 (0.0%)	4 (22.2%)	11 (61.1%)	3 (16.7%)	3.9	47.2%/ -0.0%
Program On/Off due to electricity prices	0 (0.0%)	0 (0.0%)	8 (44.4%)	8 (44.4%)	2 (11.1%)	3.7	33.3%/ -0.0%
Fire alarm	0 (0.0%)	4 (22.2%)	3 (16.7%)	6 (33.3%)	5 (27.8%)	3.7	44.4%/ -11.1%
Messages from the energy supplier directly to Tablet / Smartphone	0 (0.0%)	2 (11.1%)	5 (27.8%)	8 (44.4%)	3 (16.7%)	3.7	38.9%/ -5.6%
Intruder detector	0 (0.0%)	6 (33.3%)	1 (5.6%)	7 (38.9%)	4 (22.2%)	3.5	41.7%/ -16.7%
Tips on saving measures	0 (0.0%)	3 (16.7%)	7 (38.9%)	6 (33.3%)	2 (11.1%)	3.4	27.8%/ -8.3%

Comment from a respondent: “A preferable service would be linkage to the weather forecast in order to be able to regulate the indoor temperature.”

Appendix B

Interview – User experience

1. Intro

My name is Sofia Björnehaag and I'm currently writing my master thesis at Lund University in cooperation with E.ON. My work consists of analyzing what you as a test users think of the HEM System. I'm neutral on the issue and have no desire on how you answer the various questions on the contrary; I want to hear scattered opinions. The questions I ask are in no way intended to judge you, but for me to draw conclusions about what is important to different people about HEM systems. The product will hopefully in the future be found on the market and it is important that it meets customers' expectations. I have a lot of issue that we are to discuss it if I feel that we are slipping away from the topic, I will interrupt you. Please respond briefly to the questions and if you can yes or no. You are of course welcome to develop your answers if you wish.

Name:
Why participate:
Focus group: Yes / No
Something that often is malfunctioning:
Alarm installed before Employee Trial: Yes / No
Heating System:

2. Installing, learning and Design

We'll start talking a little about installations, learning and design. Then we go on to using the HEM System both from a heat and power perspective. Then user experiences of HEM System, a bit about the environment and technology, and end with control and security.

Installation
How much of the installations did you do yourself?

Did you found that something was difficult during installations?

What do you consider is reasonable for a future user of the HEM System to install themselves? E.g. smartplugs, thermostats, temperature sensor, gateway?

Learning
Do you find it difficult to learn how to use the app? What was difficult? What was easy? Is the app pedagogically structured?

Design
What do you think about the app graphic design? Like it? Why / why not? iPad/iPhone?

Do you think that the apps reflects E.ON's design profile? Improvement?

Do you think such the app visualizes your energy use in a good way?

What do you think about the design of the HEM System components? Smartplugs, thermostats, gateway, temperature sensor and alarm components.

3. Using the HEM System

How often do you use the iPad app?

Less than 1 time / week
1 day / week
A few times / week
1 time / day
Several times /day

How often do you use the iPhone app?

Less than 1 time / week
1 day / week
A few times / week
1 time / day
Several times /day

Which are the main differences in the use of the iPad/iPhone apps?

What motivate you to use apps? Conversely, what's stopping you?

Are other members of the household using HEM System? Shortly, why/why not and can they somehow get to use the system more often?

4. Services and features

Show the picture of services and features.

Which 2-3 services and features you using the most? And why? Tips on improvement?

Is there a service or feature that you think is unnecessary? Why? Tips for improvement?

Are you missing any services or features? Differences iPhone/iPad?

What do you think about the feedback rate?

Heat control
We are now to talk about the heating control.

Do you experience better thermal comfort at home now compared to before Employee Trial? A more even and comfortable temperature?

Have you noticed any differences due to the weather and weather changes, do you think that the system keep the comfort level?

You can set the temperature for each room. Is it valuable compared to only be able to set a temperature for the entire house?

You can set the temperature for four different modes: Home, Away, Asleep and Vacation. Would you like to be able to enter more modes/fewer modes or is it okay as it is?

Do you think it is difficult to make settings regarding the temperature, do you change them often?

What is the main advantage of being able to adjust the temperature via the HEM System?

Regarding the thermal features, it there something that is malfunctioning? Something you want to change?

Service and features
Have you tried to use the Schedule? For how long did you use the scheduling/why not? What works well/not so well?

Do you use Home/Away/Asleep /Holiday function? How often? Have you set different temperatures and electronics for the four modes? What do you think about the function?

How often do you use the Analysis Mode? What do you analyse? Do you think that you learned something by using Analysis Mode? What works well/not so well?

How long have you had the alarm installed? How do you think that the alarm is working? What is working/not working?

5. Control

In order to achieve a sustainable energy production concerning both cost and environmental aspects, it is important to be able to control the production load and get customers to consume electricity when there is much available. This is one of the reasons for developing smart grids. For the smart grid to function optimally it requires that the customer uses electricity at the right time. The big question is how to motivate the customers to do this? And Saving Mode is an attempt.

Have you tried using Saving Mode? For how long did you have Saving Mode on /why not?

For which electrical appliances did you have Saving Mode enabled?

What works well / not so well?

Do you ever analyse Price 24h? Do you think that you would choose to use energy when it is cheap if you were paying according to a time tariff?

By making various settings you can select what HEM System may control in your home. In Saving Mode feature, you can for example select between three different levels when electrical appliances may be switched off due high electricity prices. However, you cannot control the when this may occur since this is controlled by the varying electricity prices.

Do you think that the amount of control that Saving Mode provides by settings is satisfactory? Suggestions on further settings?

Are there situations when you would be willing to completely let the HEM System control the electrical appliances at home? If so, when and in which appliances?

Are there situations when you would be willing to completely let the HEM System control the heat settings at HEM system? If yes, when and in which rooms?

What I am trying to figure out is when comfort is more important than energy savings, what do you think? Conversely, when energy savings is more important than comfort?

6. Technology and environment

Now let's talk a little about technology and the environment.

Technology

Do you have a keen interest in technology? Did you have any previous experience of using tablets and smartphones? What do you think of technology Often a tool or obstacle?

Environment

Do you think that environmental issues are important? Do you see yourself as an eco-friendly person?

Would you like to have the opportunity to read your environmental impact in the app? Do you think it would motivate you to save energy?

7. Energy use

Now I will ask some questions about energy use.

Do you think that you were well aware of your energy use before the trial? Did you reflect over the households' energy use? Do you do it more often now?

Have you noticed any changes in the way you or others in your household are using electricity and or heat now? What do you do differently? Give me an example of a situation where you/anyone in your household do things differently now.

What do you think the change is due to? (the HEM system / the trial / impact)

How much would the following scenarios motivate you to save energy?

Scenario	Not at all	To some extent	Rather much	Very much
Cost savings				
Community comparison				
Comparison with the own previous energy use				
Some form of competition				
Own goal target				
Coaching from E.ON				

Knowledge and understanding

Do you think that using HEM system has increased your knowledge and insight regarding energy use, please give examples? Why / why not?

Test Question: Do you know what your fridge or freezer consume? Do you know what your TV consumes?

8. Control and privacy

Now we discuss control, security and privacy. In order to enable analysis of energy usage and example settings of heat through the Schedule it is required that data is stored on a server (at home or at E.ON). Right now your energy data is stored on a server at E.ON.

How do you feel regarding that a utility can read when you e.g. when you watch TV or make coffee? Do you feel that it restricts with your privacy?

How much of your energy data would you be willing to share to a utility?

For what purpose do you think it's okay to use your energy data? E.g. research, evaluation of customer types, sales.

What do you think of having an alarm system in combination with the HEM system?

Trust in the HEM System (make a mark):

Do not trust at all in the HEM system									Fully trust in the HEM System
1	2	3	4	5	6	7	8	9	10

9. In conclusion

Willingness to pay

Presuming that the HEM System works without major problems, would you like to keep the system in the future without having to pay for it?

Presuming that the HEM System works without major problems, would you be willing to pay for the system?

If you were to buy for the HEM System, what would you be willing to pay per month for the service, without paying any up-front costs?

If you were to buy the HEM System, what would you be willing to pay for all components (not iPad/iPhone) without having to pay a monthly fee then?

Finally, to summarize ...

Which are the main benefits of HEM System?

What are the main drawbacks of the HEM system? What should be improved?

Have the HEM system met to your expectations?

Value the services and feature that are included or might be included in the HEM System:

Service	Not at all important	Not important	Neither nor	Important	Very important
Energy analysis					
Read real-time electricity use					
Read last week electricity use					
Read last month electricity use					
Read last year's electricity use					
Comparison electricity use with former periods					
Read environmental impact					
Control and comfort					
Overview and control electrical appliances					
On/Off electrical appliances					
Home/Away/Asleep/Vacation					
Timer feature					
Schedule					
Remote control					
Internal switches					
Indoor climate					
Setting temperature					
Setting temperature according to weather forecast					
Read indoor temperature					
Safety					
Fire alarm					
Intruder detector					
Snapshots of the home					
Connection to alarm company					
Auto switch off e.g. coffee machine					

Service	*Not important*	*Neither nor*	*Important*	*Very important*	*Not at all important*
Message from energy supplier					
Tips on saving measures					
Warning for abnormal energy use					
Cost/energy savings					
Saving Mode for heat use					
Saving Mode for power use					
Energy coach					
Bill tracker					
Reward system for good energy use					
Read cost savings					
Community comparison					

Appendix C

	Service	*Not at all important*	*Not important*	*Neither nor*	*Important*	*Very important*	*Likert scale*	*Response rate*
1	Setting temperature	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (26.3%)	14 (73.7%)	86.8%/ -0.0%	19/19
2	Remote control	0 (0.0%)	0 (0.0%)	0 (0.0%)	7 (36.8%)	12 (63.2%)	81.6%/ -0.0%	19/19
3	Display indoor temperature	0 (0.0%)	0 (0.0%)	2 (11.1%)	6 (33.3%)	10 (55.6%)	72.2%/ -0.0%	18/19
4	On/Off electrical equipment	0 (0.0%)	1 (5.6%)	2 (11.1%)	4 (22.2%)	11 (61.1%)	72.2%/ -2.8%	18/19
5	Overview and control of electrical equipment	0 (0.0%)	0 (0.0%)	1 (5.3%)	9 (47.4%)	9 (47.4%)	71.1%/ -0.0%	19/19
6	Display real time electricity use	1 (5.3%)	0 (0.0%)	2 (10.5%)	5 (26.3%)	11 (57.9%)	71.1%/ -5.3%	19/19
7	Saving mode heating use	0 (0.0%)	0 (0.0%)	2 (10.5%)	9 (47.4%)	8 (42.1%)	65.8%/ -0.0%	19/19
8	Home/Away/Asleep/Vacation function	0 (0.0%)	0 (0.0%)	3 (15.8%)	8 (42.1%)	8 (42.1%)	63.2%/ -0.0%	19/19
9	Integral switches	0 (0.0%)	2 (10.5%)	1 (5.3%)	8 (42.1%)	8 (42.1%)	63.2%/ -5.3%	19/19
10	Comparative electricity use to former periods	0 (0.0%)	0 (0.0%)	3 (15.8%)	9 (47.4%)	7 (36.8%)	60.5%/-0.0%	19/19
11	Scheduling On/Off	0 (0.0%)	1 (5.3%)	3 (15.8%)	7 (36.8%)	8 (42.1%)	60.5%/ -2.6%	19/19
12	Fire alarm	0 (0.0%)	0 (0.0%)	5 (26.3%)	6 (31.6%)	8 (42.1%)	57.9%/ -0.0%	19/19
13	Intruder detector	0 (0.0%)	0 (0.0%)	5 (26.3%)	6 (31.6%)	8 (42.1%)	57.9%/ -0.0%	19/19
14	Display last month electricity use	0 (0.0%)	1 (5.3%)	2 (10.5%)	10 (52.6%)	6 (31.6%)	57.9%/ -2.6%	19/19
15	Display last year electricity use	0 (0.0%)	1 (5.3%)	3 (15.8%)	8 (42.1%)	7 (36.8%)	57.9%/ -2.6%	19/19
16	Display last week electricity use	1 (5.3%)	1 (5.3%)	1 (5.3%)	11 (57.9%)	5 (26.3%)	55.3%/-7.9%	19/19
17	Automatic switch off for e.g. coffee machine	0 (0.0%)	0 (0.0%)	6 (31.6%)	6 (31.6%)	7 (36.8%)	52.6%/ -0.0%	19/19
18	Timer function	0 (0.0%)	2 (10.5%)	1 (5.3%)	12 (63.2%)	4 (21.1%)	52.6%/ -5.3%	19/19
19	Saving mode electricity use	1 (5.3%)	1 (5.3%)	3 (15.8%)	8 (42.1%)	6 (31.6%)	52.6%/ -7.9%	19/19
20	Alert to alarm company/Emergency service alert	2 (10.5%)	1 (5.6%)	2 (11.1%)	8 (44.4%)	5 (27.8%)	50.0%/ -13.9%	18/19
21	Setting temperature weather forecast	0 (0.0%)	1 (5.6%)	6 (33.3%)	6 (33.3%)	6 (33.3%)	47.4%/ -2.6%	19/19
22	Out-of-home snapshot check	0 (0.0%)	1 (5.3%)	5 (26.3%)	9 (47.4%)	4 (21.1%)	44.7%/ -2.6%	19/19
23	Display energy savings	0 (0.0%)	1 (5.3%)	4 (21.1%)	11 (57.9%)	3 (15.8%)	44.7%/ -2.6%	19/19
24	Tips on saving measures	1 (5.3%)	3 (15.8%)	3 (15.8%)	7 (36.8%)	5 (26.3%)	44.7%/ -13.2%	19/19
25	Alert abnormal energy use	0 (0.0%)	1 (5.6%)	4 (21.1%)	10 (55.6%)	3 (16.7%)	44.4%/ -2.8%	18/19
26	Community comparison	1 (5.3%)	1 (5.3%)	4 (21.1%)	10 (52.6%)	3 (15.8%)	42.1%/ -7.9%	19/19
27	Messages from the energy	1 (5.3%)	2 (10.5%)	6 (31.6%)	5 (26.3%)	5 (26.3%)	39.5%/ -10.5%	19/19

	supplier directly to tablet/ smartphone							
28	Bill tracker	0 (0.0%)	2 (10.5%)	5 (26.3%)	11 (57.9%)	1 (5.3%)	34.2%/ -5.3%	19/19
29	Energy rewards	0 (0.0%)	6 (31.6%)	6 (31.6%)	3 (15.8%)	4 (21.1%)	28.9%/ -15.8%	19/19
30	Display environmental impact	0 (0.0%)	4 (21.1%)	6 (31.6%)	8 (42.1%)	1 (5.3%)	26.3%/ -10.5%	19/19
31	Energy saving coach	1 (5.3%)	4 (21.1%)	7 (36.8%)	6 (31.6%)	1 (5.3%)	21.1%/ -18.5%	19/19