Use and Adoption of Interactive Energy Feedback Systems

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Feedback is considered as one of the most effective ways to increase people's awareness of energy consumption. Literature commonly indicates that energy savings between 5-12% can be attained when households get feedback on their consumption. However, to assess the actual saving potential of energy feedback systems it is essential to investigate if, and how, people use the systems – if they adopt them into their everyday life. This paper presents findings from a six-months field study in which 23 households were given online feedback on their consumption. The purposes of the study were to evaluate (i) the effects of interactive energy feedback on the households' electricity consumption and (ii) the extent to which they used the feedback web portal. In general, the participants were positive but the use of the portal was low, the dropout rate high and most households did not decrease their energy consumption. However, six highly motivated households used the portal frequently and decreased their consumption. The findings suggest that access to energy feedback does not per se make people utilize the information. However, if motivated people use energy feedback systems frequently it can increase their awareness and support energy conservation.

Key words: Energy feedback, Energy conservation, Sustainable behaviour

1. Introduction

Energy is an intangible resource and this characteristic contributes to people being generally unaware of their consumption. One way to make the consumption more visible, increase awareness, and encourage energy conservation is to provide energy feedback [5]. Studies indicate that energy savings between 5-12% can be attained when households get feedback on their consumption through, for instance, energy monitors or online feedback [3, 4] and many interactive energy feedback systems are now available on the market to support consumers to reduce their consumption. Darby [3], Fischer [4], and Abrahamse et al. [1] all conclude, after having compared different studies, that feedback is most effective when given frequently over longer periods of time. Thus, for feedback to be effective in encouraging sustainable behaviours and support energy conservation it must be utilized regularly [10]. It depends on people using the systems, accessing the feedback, embracing the information, and subsequently changing their behaviour. To be able to evaluate the actual effectiveness of the systems, it is thus essential to study the consumer's uptake of the systems. Nevertheless, even though many studies have assessed whether or not energy feedback systems can bring about energy savings (e.g. [1, 3, 4]), few studies have been dedicated to people's experiences of using feedback systems and whether or not they are willing to adopt the new technology into their everyday life.

To make inferences on the effectiveness of energy feedback, a six-month field study in which 23 households participated aimed to assess (i) what effect interactive energy feedback can have on households' electricity consumption and (ii) to what extent people use a web portal providing energy feedback over time. This paper specifically addresses the households' use and acceptance of the system and relates the findings to the households' motivation for energy conservation prior to the study. The potential for adoption and long-term use of energy feedback systems is explored by addressing the following main questions: (a) To what extent did the participating households use the energy feedback web portal? What usage practices emerged over time? and (b) What factors influenced their use? Did, for instance, the households' initial level of motivation for energy conservation influence their use of the system?

2. Framework

As computers and mobile phones have become part of everyday life, it has been suggested that feedback provided online through these media has high potential of being used during everyday activities [2, 4, 11]. However, Wallenborn et al. [11] concluded that even though people might be initially interested and positive towards a feedback system it does not automatically mean that they will continue to be positive or adopt the system over time. In fact, most studies on energy feedback report high dropout rates and it has been problematic to confirm long-term effects. Studies that have tried to evaluate medium to long-term results have not been able to report any sustained effects [9].

According to Rogers [7] several factors influence the process of adoption: the characteristics of the innovation (e.g. perceived relative advantage, compatibility with values and needs, and ease of use), but also the channels used for communication, the social system in which the innovation is introduced, and time over which an individual passes from first knowing about the innovation through to adopting (or rejecting) it. Knowledge of the innovation and its functions is a prerequisite for adoption but the individual must also form a positive attitude towards the innovation. A positive attitude may lead the individual to decide on adopting or rejecting the innovation. One cannot, however, speak about adoption until the individual has put the innovation into actual use, making use part of everyday life.

Understanding the adoption of energy feedback systems, one has to first consider the adoption of the information channel and second the adoption of the specific system made available through the channel. In Sweden the penetration of computers, mobile phones and the Internet is high (> 90%) but this does not necessarily mean a high use frequency among all with access. A low initial use of, e.g. the computer and the Internet could create a first threshold to the adoption of a web based feedback system, while a second threshold could be shaped by the feedback being perceived as e.g. offering no benefits and/or being difficult to use. The benefits must be perceived as worth the effort associated with learning how to use, and integrating the use of the new system into everyday routines. Adopting new energy use behaviour is then yet another step. One can thus assume that motivation plays an important role.

3. Study design

3.1 The energy feedback system

The evaluated interactive energy feedback system, *Eliq Online,* was developed in 2011 and pilot tested during the field study. The system included an add-on energy meter that registered the household's electricity consumption via the electricity meter, an energy hub that stored and sent the energy data to an online database, and a web portal that visualised the energy data and provided energy related information (see Figure 1). The web portal provided several types of feedback on electricity consumption, i.e. real-time feedback, historical comparisons, and normative comparisons through energy challenges. In addition, monthly energy reports were provided and interactive evaluation tools could be used to analyse the individual household's electricity consumption based on different parameters. The feedback was provided as aggregated data on a household level. The users could communicate with individuals in other households by posting comments on the web portal in which they could compare consumption levels, discuss, and give advice on energy conservation measures.

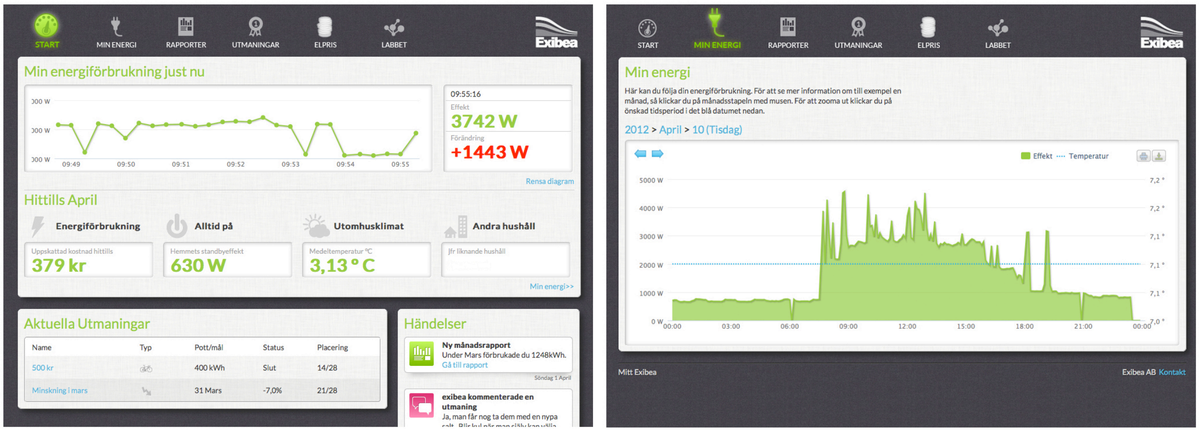

Figure 1. Example images of the web portal interface (text in Swedish)

3.2 Participants

Households had to meet three main criteria to be eligible to take part in the study. First, only residential households that had access to their energy meter could partake in the study as the energy feedback system used meter readings to collect data. Second, Internet access was vital to be able to use the web portal. As energy savings were calculated by comparing the consumption during the previous year with the test period and follow-up period, households that had moved the previous year were not qualified for the study. The majority of households were recruited from a previous interview study, in which a person from the household had been interviewed on the topic of energy conservation. Two additional households were recruited from the circle of acquaintances. Throughout the recruitment process attention was paid to enlist households with different characteristics and different levels of initial motivation for energy conservation. Most previous studies have either recruited highly motivated people with an already high interest in energy conservation or not specified the participants' initial level of motivation [1] but to be able to generalise results, it is also important to investigate if, and how, people with different levels of motivation use the systems [4].

In total, 23 households located in the city of Gothenburg (on the west coast of Sweden), or in nearby communities, were recruited. One person from each household volunteered to represent the household throughout the study. The number of inhabitants, the household income, the education levels, the type of house, the size, and the type of heating system varied amongst the households (see Appendix, Table A1). Furthermore, the households' motivation for energy conservation prior to the study, as expressed by the households' representatives, ranged from high to low initial motivation. While households with high motivation were already engaged in energy efficient behaviours, had invested in energy efficient technologies, and wanted to learn more about their consumption, households with medium to low motivation were generally less engaged in energy conservation. Participation in the study was free of charge and all households volunteered for the study.

3.3 Procedure and data collection

The study was designed with a twelve-months baseline period prior to the test, a six-months test period (January - June 2012) during which the households had the energy feedback system installed, and a six-months follow-up period. Data on the participating 23 households' monthly electricity consumption for the full 24 months was collected by self-reports, from electricity bills and/or provided by the electricity distributor. Furthermore, the electricity distributor in Gothenburg provided data on the monthly household electricity consumption for a large sample of comparable households (43,237 households during 2011 and 43,789 households during 2012) that became a control group.

Previous studies have rarely collected or analysed data on how often people access the feedback or how they use the systems. The studies that provide data on usage usually do so by means of self-reports. However, self-reported usage data might be incorrect as people sometimes do not recall events accurately or choose to portray them incorrectly. Without being able to relate the observed energy savings to people's use of the system it is difficult to tell whether or not the observed effects could be attributed to the feedback provided. To assess the participating households' use of the web portal in this study, their activity on the portal was automatically monitored in detail throughout the six months, registering logins, page visits, and page paths.

Three online surveys were distributed to the households' representatives, one prior to the test period, one two months after the start of the test period, and one after six months when the test period had ended. The first survey collected data on the households' demographic characteristics and the two following surveys checked for any changes since the start of the study. The latter surveys also evaluated aspects related to the use of the web portal; data on technical limitations, devices used for accessing the web portal, and perceived barriers to use were collected through multiple choice questions and free text answers. The households' general impression of the web portal and their attitudes towards using a similar system again were also measured by means a five-point Likert scales. Furthermore, the third survey assessed the households' acceptance of the portal by measuring trust, perceived benefits, perceived ease of use, and compliance with needs using seven-point semantic differential scales [8].

3.4 Data analysis

The households' use of the web portal was analysed to determine each household's use-frequency and their activity on the portal. The number of logins per month was used as main determinant and the number of page views per visit was calculated to further assess the activity. The activity was found to vary considerably; therefore, the households with high activity were compared to those with low activity during the subsequent analysis. However, any statistical analysis of the consumption data was ruled out due to the low number of households in each group. Instead, savings in electricity consumption were calculated by comparing the average consumption during the test and follow-up periods with the corresponding consumption the previous year. This way, the influence of seasonal changes was reduced as the different conditions during specific seasons were taken into account. The differences in electricity consumption for the test period, the follow-up period, and the full year were calculated in percentage according to the following formula:

$$\text{Difference in consumption} = \frac{(\text{Average consumption during 2012 - Average consumption during 2011})}{(\text{Average consumption during 2011})} * 100$$

In the same way, the change in average consumption was calculated for the control group of households in Gothenburg to assess annual differences in consumption due to e.g. weather and other regional influences.

The survey data measuring the households' attitudes towards the web portal was analysed applying a qualitative approach and compared to the participants' level of activity. To assess the four constructs measuring the households' acceptance for the web portal, the median values were calculated and box plots with an interquartile range with maximum and minimum values were used to indicate the extent to which the data varied.

4. Findings

Of the 23 recruited households, 15 completed all surveys and provided energy data for the 24 months, four households did not provide complete energy data but completed all three surveys, and three households neither completed the surveys, nor provided complete energy data. Households with high or medium initial motivation for energy conservation completed the study to a higher degree than households with low motivation.

4.1 Use of the web portal

Most households that reported an initial high motivation for energy conservation used the web portal during more months than households with medium or low motivation (see Table 1). When asked whether or not they wanted to continue using the web portal after the test period, four out of the 23 households responded positively. Their access to the web portal was prolonged but only two (H7 and H21) actually continued to use the portal regularly during the follow-up period.

Table 1. Number of months each household used the portal at least once during the test (and follow-up) period.

High initial motivation		Medium initial motivation		Low initial motivation	
Household ID	Number of months with activity	Household ID	Number of months with activity	Household ID	Number of months with activity
H3	5	H2	1	H1	2
H7	5 (4)	H4	3	H6	1
H8	4	H5	2	H9	2 (1)
H10	6	H13	1	H11	1
H15	4	H16	2	H12	2
H21	6 (6)	H17	4	H14	2
H22	6 (2)	H19	2	H18	0
H23	1	H20	2		

The monthly number of logins on the web portal varied between individual households over time. Most households used the web portal initially but decreased or even ceased their use of the portal after the first couple of months. Figure 2 shows that six households, all with high initial motivation for energy conservation, used the web portal more frequently and more regularly compared to the other households. Nevertheless, the number of logins per month varied also amongst the six households with high use frequency. Except their level of motivation, no additional characteristics were observed for the six households with high use frequency compared to the remaining 17 households.

When online, the 23 households accessed different types of content on the web portal. Figure 3 gives an overview of the number of households that each month accessed a page that provided one of the different types of content. Overall, the number of households that accessed the content was high in the beginning of the study but decreased over time. While the six households with high use-frequency continued to access most of the content throughout the study, the remaining 17 households did not. The content accessed most often by the 23 households was real-time feedback, historical comparisons, energy challenges, and energy reports. The interactive evaluation tools were accessed to a lesser extent. The portal was used any day of the week and, apart from frequency, no difference in use patterns could be observed between the households. The representatives for the 19 households that completed the surveys stated that they had all used a computer to access the web portal. In addition, five sometimes used a mobile phone and three sometimes a tablet computer. Most accessed the web portal solely at home while some stated that they had also logged in on the web portal when at work (four households), when visiting friends or family (two households), and at various other locations (one household). The six households that used the web portal more frequently used more devices and accessed the web portal at more locations than the remaining 13 households did.

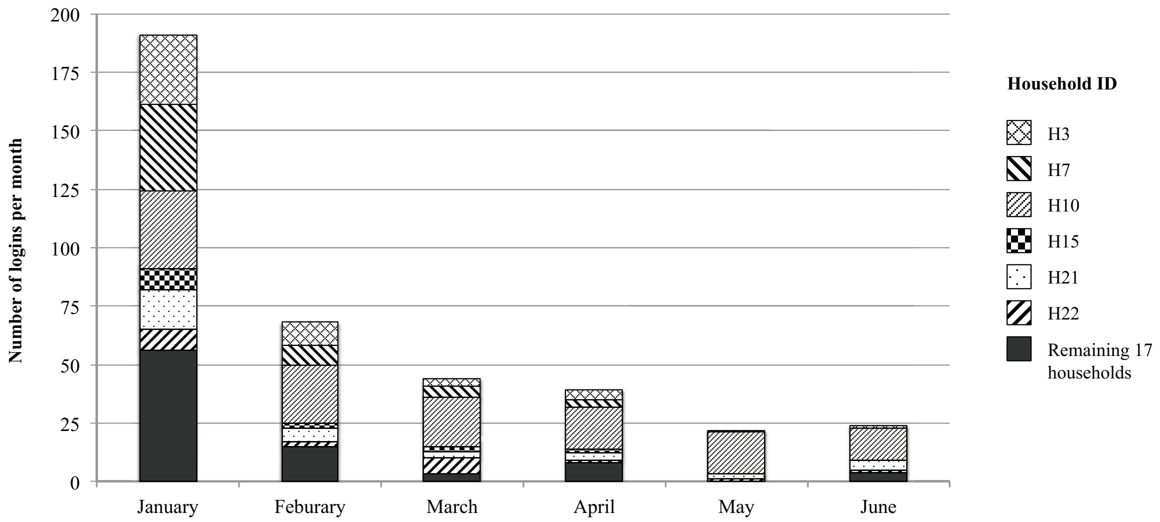

Figure 2. Frequency of use

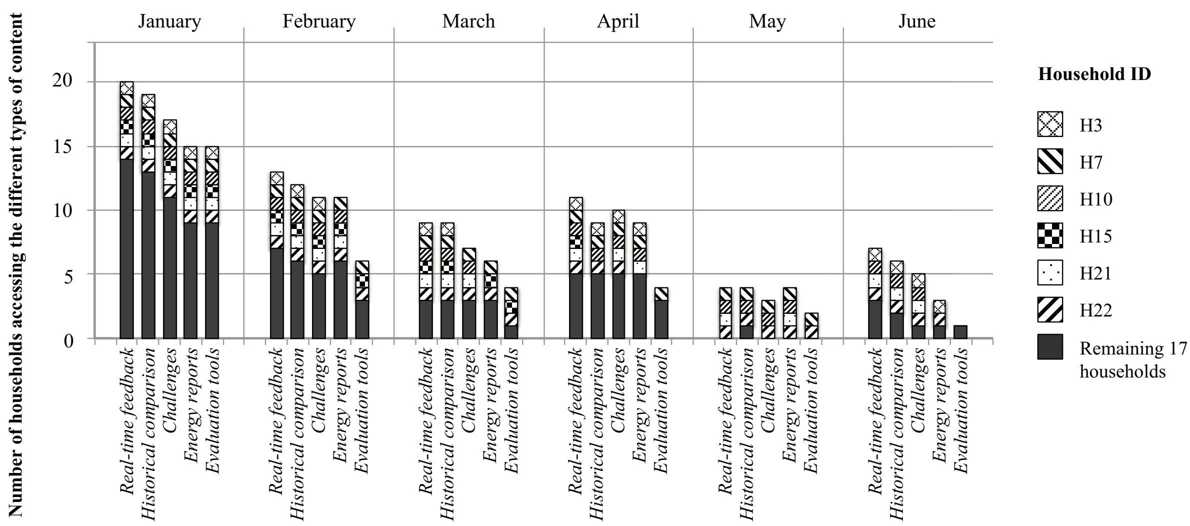

Figure 3. Number of households accessing different types of content

4.2 Effects on electricity consumption

The findings show no substantial decrease in average electricity consumption during the test period for the group of 15 households that provided complete energy data. Furthermore, the group increased their average electricity consumption more than the control sample during the full year (see Table 2). However, the change in electricity consumption for the individual 15 households varied quite a lot. In general, the households that did not use the web portal to any higher degree did not reduce their consumption throughout the study. The households that did use the portal regularly managed to reduce their consumption during the six-months test period compared to the previous year. The group of households with high use-frequency, and complete energy data, managed to reduce their total consumption by 9.0%, from 48,055 kWh to 43,717 kWh, during the test period. They did not, however, manage to reduce their average consumption during the follow-up period but their increase was not as high as the average in Gothenburg. When looking at the average consumption on a yearly basis, the five households managed to reduce their consumption by 2% while the control sample had a 3.9% increase. The two households that continued to use the web portal also during the follow-up period, managed to reduce their average electricity consumption by 13.6% or 1,150 kWh during the follow-up period and by 9.9% or 1,906 kWh during the full year.

Several households reported changes that might have affected their consumption level during 2012 compared to 2011. Of the five households that frequently used the web portal, one reported that they had had guests for more than a week. Three of the 10 remaining households that completed the surveys reported an increased number of members in the household, six reported that they had been away from home for longer than a week, four had also had guests staying over for more than a week, and six reported that they had spent more time at home than the previous year.

Table 2. Change in average electricity consumption 2012 compared to the same period 2011

	Number of households	**Test period** (6 months)	**Follow-up period** (6 months)	**Full year** (12 months)
All households with complete energy data	15	-0.2 %	14.8 %	6.1 %
Households with low activity	10	5.1 %	18.4 %	10.8 %
Households with high activity during the test period	5	-9.0 %	8.4 %	-2.0 %
Households with high activity during the test and follow-up periods	2	-7.0 %	-13.6 %	-9.9 %
Control sample of households in Gothenburg	43,237 (2011) 43,789 (2012)	-3.5 %	14.1 %	3.9 %

4.3 User acceptance of the web portal

The households' general impression of the web portal was mostly positive; four out of the 19 households that completed the surveys were very positive, seven were moderately positive, seven were neutral and one did not have an opinion. Many of the households were also positive towards using the web portal or similar energy feedback systems in the future. In general, the households' representatives expressed a moderate to high level of acceptance for the web portal in regards to their needs, the perceived ease of use, their trust for the web portal, and the perceived benefits (see Figure 4). The majority considered the web portal to be an appropriate tool for providing energy feedback and some even considered it to be a crucial tool when trying to lower their consumption. Most households, in particular the six with high activity, found the web portal easy to get started with, easy to use, easy to navigate, and also considered it easy to understand the information provided online. However, a few households expressed the opposite, i.e. they found it difficult to use the web portal, and difficult to understand both the information and how to act based on the provided feedback.

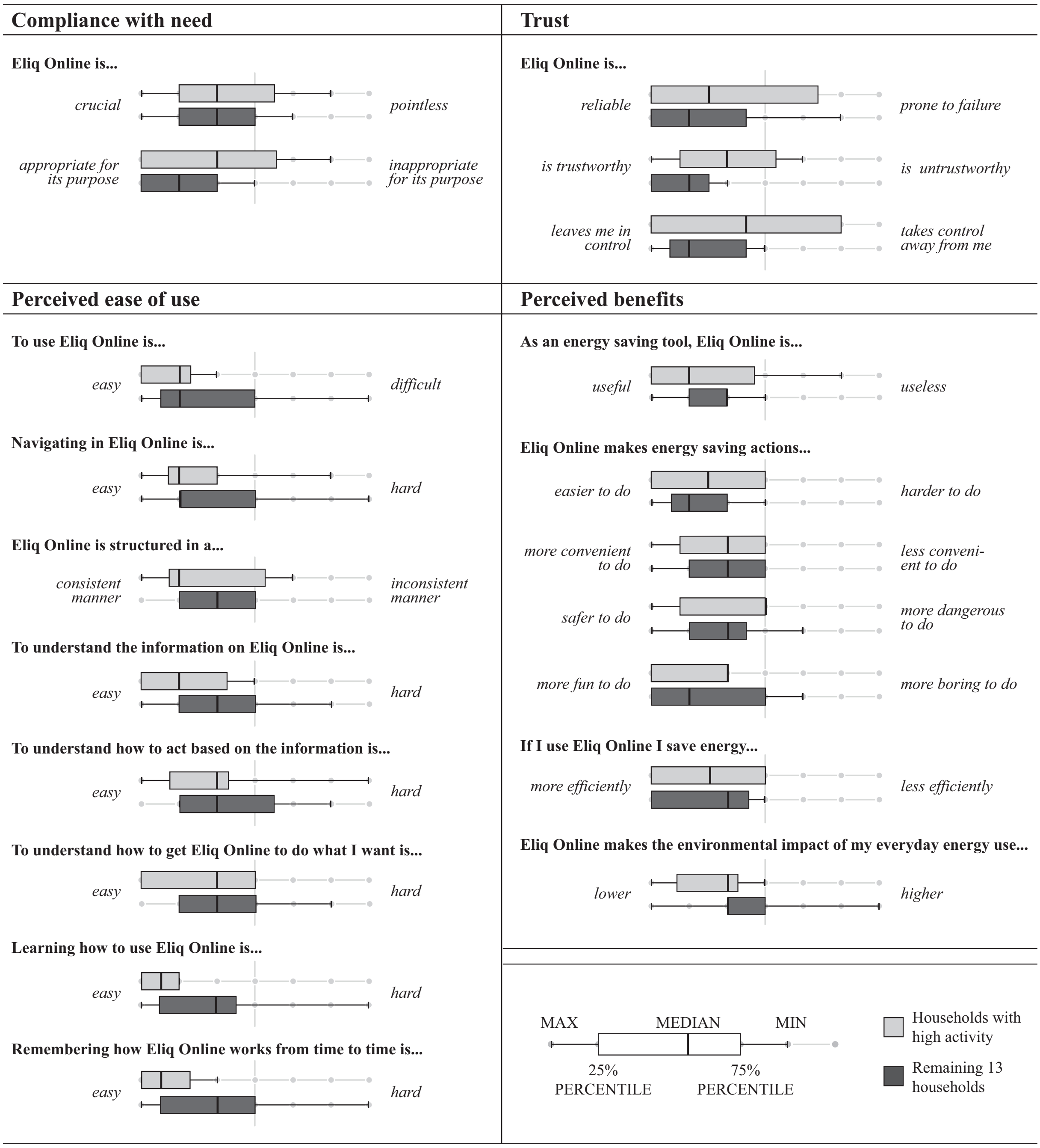

Figure 4. The households' level of acceptance for the web portal

Overall, the 19 households expressed a medium to high level of trust for the web portal. The households that used the web portal frequently were less positive than the others; some of them found the portal less reliable, less trustworthy, and felt that they did not have enough control during use. One explanation for the lower level of trust might be that they had experienced more shortcomings since they had used the portal to a higher degree than the other households. Regarding perceived benefits, the group generally found the web portal useful and capable of helping them to save energy more efficiently. Although the households expressed that the portal made their energy saving actions slightly easier and more fun, it did not to any higher degree make them safer or more convenient to carry out.

4.4 Barriers to use

When the test period had come to an end after six months, the households were asked whether or not they had been able to use the web portal as often as they wanted to. Nine out of the 19 households that completed the surveys stated that they had in fact used the portal to the extent that they wanted. However, most households also expressed several reasons to why they had not used the portal more often. The reasons are listed in Table 3 under three categories: technical and practical barriers, lifestyle barriers, and motivational barriers. Households with high initial motivation for energy conservation highlighted more technical and practical barriers while households with low motivation mentioned lifestyle barriers and motivational barriers to a higher degree.

Table 3. Number of households that highlighted different types of barriers

	Technical and practical barriers				**Lifestyle barriers**		**Motivational barriers**	
	Technical limitations and malfunctions with the system	Usability issues on the web portal	Difficulties when logging in on the web portal	Malfunctions with the device used to access the web portal	Lack of time	Prioritizing other activities	No interest in decreasing consumption	Uninteresting feedback
Number of households	6	3	1	3	13	12	3	2

Several households stated that they had not used the web portal as much as they would have preferred due to technical limitations e.g. the level of detail in consumption and weather data. Some households also experienced system malfunctions that resulted in incomplete energy data, which in turn resulted in lowered trust for the system and decreased use. Others considered it too difficult to use the web portal and the interface on smartphones was found to be particularly inadequate. A few households had trouble with their computer or Internet access during parts of the test period, which hindered them from accessing the portal. The households also reported on lifestyle barriers, e.g. many could not find the time to use the web portal and several prioritised other everyday activities instead:

> "*It did not fit my lifestyle to use the computer to log in since I never use computers during my spare time. I thought that the web portal would make me use computers more but that did not happen. I'm not a digital person, and I never will be*." (H11, authors' translation).

Furthermore, some households were just not interested in lowering their consumption or considered the information provided online to be uninteresting and unhelpful. Even some of the households that had used the web portal initially were not so motivated to continue long term. The lack of relevant functionality was mentioned as a reason:

> "*When reasonable changes and thereby savings have been made, there is no further need for the feedback system. Except perhaps an alarm function that indicates when the consumption increases rapidly*." (H3, authors' translation).

5. Discussion and conclusion

Generally, the participating households were positive towards the web portal but few used it regularly and even fewer continued to use it in the long run. The results thus comply with the findings of Wallenborn et al. [11]. The 23 participating households did not, as a group, manage to reduce their electricity consumption, but the individual households that used the web portal frequently did. The findings thus suggest that energy feedback systems can support energy conservation if used frequently. However, access to energy feedback does not per se make people utilize the information. Several barriers were observed to limit the use of the web portal, lower the users' acceptance, and hinder adoption. These included technical and practical barriers, which can be compared to Roger's 'complexity' [7], but also lifestyle barriers and motivational barriers. As similar barriers have previously been identified in other studies evaluating comparable systems [e.g. 4, 6, 10] it is suggested that the barriers are not exclusively adherent to the specific design of the system assessed in this study.

The identified barriers require different strategies in order to facilitate use, acceptance, and long-term adoption of energy feedback systems. To counteract technical and practical barriers, the design of the interfaces providing feedback must be allocated proper resources to provide good usability and relevant functionality. More research should be carried out to identify how feedback can be further adjusted to fit the target group's needs and technology usage habits. A previously suggested strategy for addressing lifestyle barriers is to make energy feedback more accessible during everyday life by providing it online where the users can access it through a medium of their choice [2, 4, 11] but, as this study shows, even if the feedback is provided through portable devices such as mobile phones and tablets, people may still be reluctant to access the information. The study indicates that one reason is that the use of the devices, through which the feedback system is provided, is not necessarily part of the users' domestic activities and routines – even though the device is accessible. This suggests that further understanding of e.g. the households' everyday activities and routines, and the usage practices of different media in everyday life, is required in order to choose the most effective channel for providing energy feedback.

In addition, the results show that non-use can be attributed a lack of interest in energy, and in changing one's energy behaviour. The households that used the web portal regularly were those that had high motivation for energy conservation before the study and wanted to explore ways of reducing their consumption but not all individuals were interested or motivated enough even though their attitude towards energy savings and/or energy feedback was positive. The findings are consistent with earlier studies [9, 11] and imply that energy feedback systems offered to the general public might not be effective for all households. Thus, energy feedback systems as a strategy to reduce energy consumption in society will be effective only for those that are willing to use the feedback system, reflect on the feedback and take measures to actively change their consumption patterns and other, more motivating strategies must be introduced in order to reach other categories of users.

Conclusively, interactive energy feedback has considerable potential to encourage energy conservation but only for a motivated target group. Further development of todays' energy feedback systems is thus important to increase use and attract more users, but engaging the whole of society to act in a more sustainable way will also require other solutions. Therefore, additional research is thus needed to fine-tune the design of energy feedback systems and to explore strategies that enable and encourage less motivated people to embrace more sustainable behaviours.

6. Acknowledgments

This study was financed by the Swedish Governmental Agency for Innovation Systems – Vinnova. The authors would like to thank the households that took part in the study, Göteborg Energi AB for providing data, and Exibea AB for providing the energy feedback equipment and offering technical support throughout the study.

7. Appendix

Table A1. Overview of the participating households

ID	Household representative [*Gender:Age*]	Number of household members	Household income [*1000 SEK*]	Highest level of education	Type of house	Size of house [m^2]	Type of heating system	Motivation for energy conservation
H1	M:57	3	40-50	Advanced vocational training	Detached	189	Air heat pump, Crawl space heating system	Low
H2	M:41	4	40-50	University degree	Detached	305	Direct electrical heating, Stove heater	Medium
H3	M:52	4	>50	University degree	Multi-family residential	99	District heating	High
H4	F:48	4	40-50	University degree	Detached	170	Direct electrical heating, Air heat pump	Medium
H5	F:50	4	30-40	University degree	Detached	240	Air heat pump	Medium
H6	F:45	3	30-40	University degree	Detached	143	District heating	Low
H7	M:40	6	N/A	University degree	Detached	250	Geothermal heat pump, Air heat pump	High
H8	F:53	3	>50	University degree	Detached	220	Direct electrical heating, Air heat pump	High
H9	M:38	3	>50	University degree	Detached	128	District heating	Low
H10	M:63	2	>50	University degree	Detached	136	Direct electrical heating, Air heat pump, Exhaust air heat pump	High
H11	F:48	5	40-50	University degree	Detached	140	Geothermal heat pump	Low
H12	F:43	6	30-40	University degree	Detached	100	Pellet heating system	Low
H13	F:31	2	N/A	N/A	Multi-family residential	N/A	Geothermal heat pump	Medium
H14	F:44	8	>50	University degree	Detached	470	District heating	Low
H15	F:58	1	<20	Upper secondary school	Detached	N/A	Direct electrical heating, Exhaust air heat pump	High
H16	F:35	4	30-40	Doctoral degree	Semi-detached	115	Exhaust air heat pump, Hydronic floor heating	Medium
H17	M:31	3	30-40	University degree	Detached	120	Exhaust air heat pump	Medium
H18	M:33	5	>50	University degree	Terraced	205	Direct electrical heating, Air heat pump	Low
H19	F:44	3	30-40	Doctoral degree	Detached	65	Hydronic heating	Medium
H20	M:60	4	>50	University degree	Detached	170	Geothermal heat pump	Medium
H21	M:45	1	20-30	Upper secondary school	Detached	200	Geothermal heat pump	High
H22	M:47	2	>50	Upper secondary school	Detached	130	Direct electrical heating, Air heat pump	High
H23	M:69	2	N/A	N/A	Semi-detached	114	Air heat pump	High

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