What's in it for the user? Effects and perceived user benefits of online interactive energy feedback.

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To assess the effects and benefits of computerized energy feedback, an interactive energy feedback system was implemented in 23 households and evaluated in a six-months field study. No electricity savings could be observed for the households when comparing their consumption during the test period to the consumption during the previous year. However, the use of the web portal was found to vary considerably between individual households and a correlation between use-frequency and electricity savings was observed. The five households that accessed the feedback frequently managed to reduce their electricity consumption by an average of 9% over the test period. Furthermore, many households indicated, regardlessly of their use-frequency, that they experienced positive effects of using the web portal. Some specifically expressed an increased knowledge and awareness, which to some degree empowered them to reduce their consumption and change behaviour. The findings however suggest that many aspects such as contextual factors, personal capabilities and quality of life aspects influence households' energy consumption and that access to feedback does not per se lead to savings. However, people that utilize the feedback information and are willing and capable of changing their situation can reduce their consumption and gain additional benefits that support energy conservation.

Keywords: Sustainable behaviour, Energy consumption, Feedback

1. Introduction

There is an urgent need to reduce residential energy consumption in order to achieve society's goals for a sustainable future. The domestic electricity consumption is still on the rise and is has been suggested that energy efficient household equipment can reduce consumption (Bertoldi et al., 2012). However, some argue that the positive impact of energy efficient technologies is often overshadowed by rebound-effects such as the increase of electric appliances and the augmented use of them (Hertwich, 2005). User behaviour is pointed out as a critical factor and research suggests that measures evoking changes in behaviour can influence household electricity consumption.

Providing households with feedback is considered as one of the most effective strategies and several investigations have pinpointed interactive computerized feedback as the most successful alternative for encouraging reduced energy consumption (Fischer, 2008; Wallenborn et al., 2011). Consequently, the number of digital energy monitors and online energy feedback services has drastically increased in recent years. However, few studies have been able to provide data that confirms sustained effects (Abrahamse et al., 2005; Van Dam et al., 2010; Van Dam et al., 2012).

Furthermore, most studies address only energy savings and self-reported behaviour changes when evaluating the effects that feedback could give rise to (Abrahamse et al., 2005). To explore the potential of interactive energy feedback systems in contributing to energy conservation in the long run, there is a need for more comprehensive studies that not only assess energy savings and behavioural changes during the study, but also assess other benefits that could influence and encourage future savings.

To assess the effects and benefits of computerized energy feedback, an interactive energy feedback system was implemented in 23 households and evaluated in a six-months field study. The aim of this paper is to discuss the effectiveness of the system in contributing to (i) decreased electricity consumption in regards to actual electricity savings, (ii) changes in behaviours related to energy use, and (iii) changes in behavioural determinants considered to have an impact on energy conservation behaviour, e.g. perceived motivation, awareness, knowledge, and self-efficacy. Furthermore, the paper discusses the benefits perceived by the users in relation to contextual factors that influence their ability to reduce consumption.

2. Effects of energy feedback

Feedback as an intervention is regarded as particularly effective for bringing about new behaviours and habits when given frequently over longer periods of time and when it is possible to assess the effects of specific actions on consumption. In addition, several studies imply that interactive computerized energy feedback, offering multiple feedback options and interactive elements that engage the users, has high potential to be successful (Brandon and Lewis, 1999; Fischer, 2008; Wallenborn et al., 2011). Literature suggests that providing feedback on energy consumption usually results in savings of between 5 and 12 % (Darby, 2006; Fischer, 2008). Furthermore, several studies have confirmed that feedback on consumption can have a positive effect on peoples' everyday energy behaviours (Abrahamse et al., 2007; Ueno et al., 2006; Van Dam et al., 2010). Even though many studies have evaluated energy savings and behaviour changes, few other positive effects of energy feedback have been studied when evaluating the effectiveness of feedback interventions. Steg and Vlek (2009) recommend that studies aimed to evaluate the effectiveness of an intervention should not only monitor changes in environmental impact (e.g. energy use) and in behaviour, but also consider changes in behavioural determinants and people's perceived quality of life. Observed changes in behavioural determinants can increase the understanding of why the intervention was successful or not while input on people's quality of life can reveal how people experience the effects of energy conservation in their daily life. However, a review of intervention studies aimed at household energy consumption (Abrahamse et al., 2005) reveals that individual intervention studies rarely address all these aspects simultaneously, which makes it difficult to evaluate and understand the actual effectiveness of e.g. feedback interventions.

Behavioural determinants, i.e. factors considered to influence behaviour, have been studied extensively in different fields and are included in several models of consumer behaviour and behavioural change (see e.g. Jackson, 2005). Steg and Vlek (2009) categorise the factors influencing environmental behaviour as motivational factors, contextual factors or habitual factors. Motivational factors are related to people's reasoning behind their behavioural decisions but also to psychological antecedents e.g. attitudes, values, beliefs, moral obligations, personal norms and affective motives (see e.g. Gatersleben et al., 2002; Jackson, 2005). Since behaviours are usually embedded in a social context, social norms and altruistic obligations e.g. are also believed to influence motivation (Jackson, 2005). Furthermore, in regards to motivational factors, determinants such as awareness, knowledge, self-efficacy and locus of control have been suggested to affect behaviour in different settings (Ajzen, 2002; Bandura, 1977; Thøgersen and Grønhøj, 2010). Self-efficacy is concerned with people's perceived capability of performing a behaviour (Bandura, 1977) while locus of control reflects people's perceived possibility of influencing the outcome of the behaviour (Ajzen, 2002). The predicting power of the behavioural determinants and their positive influence on behaviour have been tentatively confirmed in several different contexts including studies evaluating feedback interventions. For instance, Brandon and Lewis (1999) evaluated whether or not certain environmental attitudes, demographic characteristics, and behavioural and structural potentials for change increased people's savings when provided with feedback on their energy consumption. They found that people with positive environmental attitudes were more likely to change their behaviour than people with less positive attitudes. Thøgersen and Grønhøj (2010) assessed the influence of different types of behavioural determinants on electricity consumption, e.g. behavioural intentions, personal norms, and self-efficacy on electricity consumption, and found that internalized norms and self-efficacy highly influenced saving efforts.

Behavioural determinants have mostly been studied as predicting factors of behaviour and reviews on interventions studies aimed at encouraging energy conservation specifically indicate that few studies have explored the effects of energy feedback on behavioural determinants (Abrahamse et al., 2005; Fischer, 2008). Since behavioural determinants are considered to influence both current and future behaviour, it is valuable to evaluate changes in behavioural determinants when assessing the effectiveness of energy feedback. Some energy feedback interventions studies have in fact evaluated changes in behavioural determinants as additional benefits besides energy savings and changed behaviour. Grønhøj and Thøgersen (2011) observed that providing energy feedback through a feedback display increased the participants' self-efficacy and empowered them to reduce their energy consumption. Furthermore, the feedback stimulated increased communication within families and increased both awareness and knowledge regarding energy consumption in relation to specific activities. These results are in line with the findings of Hargreaves et al. (2010) and Wallenborn et al. (2011) concerning learning effects. Also Abrahamse et al. (2007) and Hutton et al (1986) also identified increased knowledge as an effect of feedback by assessing the participants' level of knowledge through a quiz before and after an energy feedback intervention.

In summary, studies evaluating the effectiveness and benefits of energy feedback have mainly focused on evaluating energy savings and behaviour changes. Few of these studies have investigated behavioural changes in regards to people's perception of their quality of life or assessed changes in behavioural determinants. The studies that have explored people's experiences and perceived benefits of energy feedback have seldom assessed behaviour changes or energy savings quantitatively. The study presented in this paper sought to narrow this knowledge gap by evaluating the effectiveness of an energy feedback system by assessing energy savings, changes in energy related behaviours, changes in behavioural determinants (i.e. changes in attitudes, awareness, knowledge, self-efficacy, locus of control, intention), and quality of life aspects.

3. Study design

3.1. Eliq Online - The energy feedback system

The interactive energy feedback system, Eliq Online, that was evaluated during the study was developed in 2011 and piloted during the field test. The system included several elements: an add-on energy meter that registered the household's electricity consumption, an energy hub that stored and sent the energy data to an online database, and a web portal that provided the households with feedback on their consumption. The web portal, which could be accessed via any web-based user interface, visualized the energy data and provided real-time feedback, historical comparisons, and normative comparisons through energy challenges (see Figure 1). Furthermore, monthly energy reports were provided, and interactive evaluation tools could be used to analyse the individual household's electricity consumption in regards to different parameters. The users could also communicate with individuals in other households by posting comments on the web portal where they could compare consumption levels, discuss, and give advice on energy conservation measures. The feedback on the web portal was provided as aggregated data on a household level and the data was updated every 15 seconds.

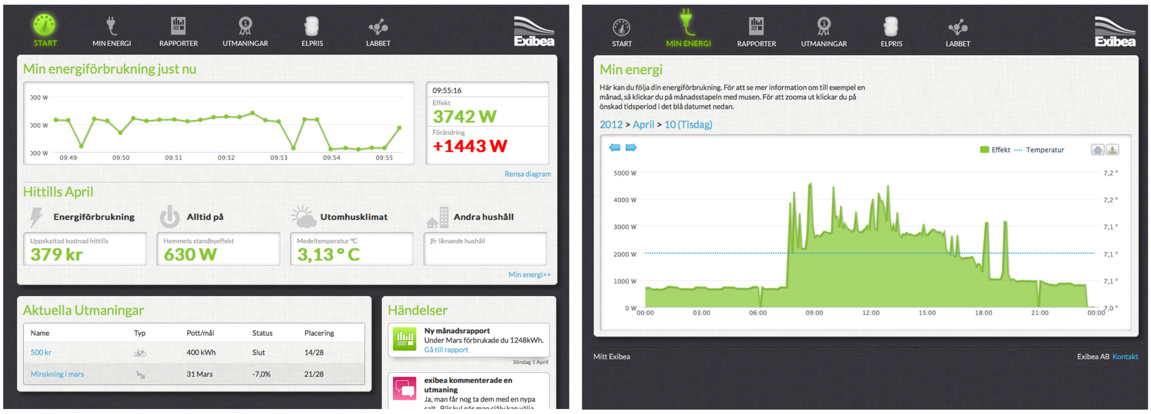

Figure 1. The interface of the interactive energy feedback web portal (in Swedish)

3.2. Participants

Three selection criteria were used when recruiting participants. First, the households had to have access to their energy meter as the energy feedback system used meter readings to collect data. Second, Internet access was vital to be able to use the web portal. Third, households that had moved the previous year were not qualified for the study, as energy savings were to be calculated by comparing the consumption during the test and follow-up period with the corresponding period from the previous year.

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 authors' circle of acquaintances. Attention was paid to enlist households with different characteristics and different levels of motivation for energy conservation.

In total, 23 households located in the city of Gothenburg (on the West coast of Sweden), or in nearby communities, were recruited for the study. One person from each household volunteered to represent the household throughout the study. 52.2% of the household's representatives were men and the average age was 46.7 years. A majority of the households, 12 households, were three-person or four-person households, six were single-person or two-person households, and five households were five persons or more. The household income, the education level, the type of house, the size, and the type of heating system differed between the households. The households also reported different levels of motivation for energy conservation prior to the study. Participation in the study was free of charge or gratification and all households volunteered for the study.

3.3. Procedure and data collection

The two-year study included a twelve-months baseline period, a six-months test period during which the households had Eliq Online installed (January - June 2012), and a six-months follow-up period. All households were invited to a meeting prior to the six months test period where they were given an introduction to Eliq Online and had the opportunity to meet the other participants.

The participating households' level of activity on the web portal was monitored and their use of the portal was automatically registered throughout the six-months test period. To assess changes in electricity consumption over the whole study, complementing data on the households' monthly electricity consumption was collected by self-report from electricity bills or provided by the electricity distributor for the full 24 months. The electricity distributor in Gothenburg also provided data on the monthly household electricity consumption for a large sample of comparable households in the region: from 43,237 households during 2011 and from 43,789 households during 2012. These were used as a control group.

Three online surveys (see Table 1) were distributed to the households' representatives, one prior to the test period (T0), one two months after the start of the test period (T1), and one after the six-months test period had ended (T2). The first survey collected data on the households' demographic characteristics, their attitudes towards energy conservation, their perceived self-efficacy, and 13 specific energy related behaviours. The two following surveys checked for any changes since the start of the study. The 13 measured energy behaviours included behaviours related to heating, lighting, major household appliances, and common electronic products. Furthermore, the two latter surveys collected data on the households' general perception of their energy related behaviours and perceived changes in behavioural determinants, due to the use of Eliq Online: in motivation to reduce consumption, in intent to reduce consumption, in locus of control, and in knowledge concerning their own situation and possible measures they could apply to reduce consumption. The data on the household's demographic characteristics were collected through multiple-choice questions while the data on behaviours and behavioural determinants were measured with five-point Likert items. The items measuring behaviours and behavioural determinants were randomly presented and either positively or negatively framed to minimize the influence of social desirability. In addition, the households could also provide additional free text comments and reflections.

Table 1. Overview of measured constructs at T0, T1, and T2

T0 *One month prior to the test period*	T1 *Two months into the test period*	T2 *One week after the six-months test period*
Demographic characteristic	Demographic characteristic	Demographic characteristic
Attitudes	Attitudes	Attitudes
Self-efficacy	Self-efficacy	Self-efficacy
Behaviours	Behaviours	Behaviours
	Perceived behaviour change	Perceived behaviour change
	Motivation	Motivation
	Intention	Intention
	Locus of control	Locus of control
	Knowledge	Knowledge

Of the 23 recruited households, 15 completed all three surveys and provided energy data for the full 24 months. Four additional households completed the surveys but did not provide complete energy data (see Table 2). As the households' use of the web portal and activity online determined the amount of feedback each household potentially received, a distinction regarding the households' use-frequency was made when analyzing the results.

Table 2. Overview of collected data in regards to the whole group and the subgroups

Collected data	Complete energy and survey data	Incomplete energy data but complete survey data	Incomplete energy and survey data	No data due to no participation
N: Total	15	4	3	1
N: High use-frequency	5	1	-	-
N: Low use-frequency	10	3	3	-

3.4. Data analysis

The households' use of the web portal was found to vary considerably and decrease over time. Therefore, the households' use-frequency, i.e. total number of logins, was used as main determinant when assessing changes in electricity consumption. Electricity savings were calculated by comparing the average consumption during the test and follow-up periods with the corresponding consumption during the previous year. This way, the influence of seasonal changes was reduced as the 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:

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

The annual differences in consumption due to e.g. weather and other regional influences were taken into consideration by assessing the change in average electricity consumption for the control group of households in Gothenburg. The survey data was decoded and negatively framed items were reverse coded. Correlations between the households' use-frequency, energy savings and the compiled survey data was analysed using the Spearman's Rank Order correlation test. A significance level of $p < 0.05$ was used to evaluate the results.

4 Findings

4.1 Electricity consumption

Changes in the households' electricity consumption were evaluated medium-term (six months) and long-term (12 months) for the group of 15 households that provided complete energy data. No substantial decrease in average electricity consumption could be observed for the group during the first six months compared to the previous year, see Table 3. Their average electricity consumption during the full year also exceeded the average change for the control group.

However, the change in individual electricity consumption for the 15 households varied quite a lot. The households that used the web portal more regularly, managed to reduce their consumption more than the other households. The households with high use-frequency reduced their consumption during the six months test period while the households with low use-frequency increased their consumption during the same period. The group of households with high use frequency 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 in consumption was not as high as the average change for the households with low use-frequency or for the control. When looking at the long-term changes in average consumption, the five households managed to reduce their consumption by 2% while the control sample showed a 3.9% increase.

Four of the households had their access to the web portal prolonged at the end of the test period when the 23 households were asked whether or not they wanted to continue using the web portal during an additional six months. Two households with high use-frequency during the test period continued to use the web portal regularly also during the follow-up period. They 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.

Table 3. Change in average electricity consumption 2012 compared to the same period 2011

	Number of households	Test period	Follow-up period	Full year
		6 months	*6 months*	*12 months*
All households with complete energy data	15	-0.2 %	14.8 %	6.1 %
Households with low use-frequency during the test period	10	5.1 %	18.4 %	10.8 %
Households with high use-frequency during the test period	5	-9.0 %	8.4 %	-2.0 %
Households with high use-frequency 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 %

A Spearman's Rank Order correlation was run to assess the relationship between the change in electricity consumption and the households' use of the web portal. The households' use-frequency, i.e. their number of logins, was tested for correlation to the households' average change in consumption for the medium-term measures (six months) and for the long-term measures (12 months) respectively, see Figure 2. There was a statistically significant positive correlation between the households' use-frequency and attained energy savings for the medium-term ($r_s(13) = -.626^*$, $p = .012$) as well as the long-term measures ($r_s(13) = -0.567^*$, $p = .028$).

Several households reported demographical and situational changes that might have affected their consumption level during 2012 compared to 2011, e.g. three of the 10 household with low use-frequency reported an increased number of household members and six reported that they had spent more time at home than the previous year.

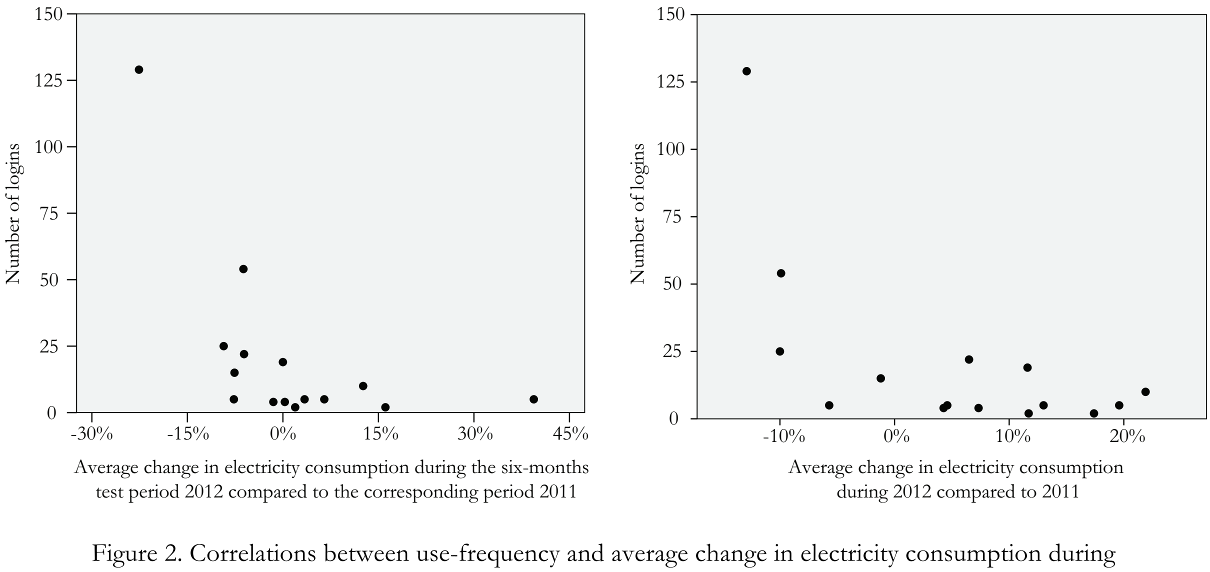

Figure 2. Correlations between use-frequency and average change in electricity consumption during a) the six-months test period, and b) the full year

4.2 Energy related behaviours

When asked whether or not the web portal had contributed to changes in everyday energy related behaviours and/or to purchases of energy saving appliances, most of the 19 households that completed the surveys indicated behavioural changes to at least a low degree and some reported purchases, see Table 4. One participant who frequently used the web portal described his experience: "*The primary function of the web portal – to present a household's consumption in a simplistic manner to increase knowledge on electricity consuming appliances - is valuable. It sparks conservation activities.*"

(Male, age 52). Regardless of the positive change perceived by some households, no significant correlation between the households' use of the web portal and their perceived change in energy related behaviours was observed at T1 or T2.

Table 4. Perceived behaviour change

Construct	Items	T1	T2	Spearman's correlation			
		Median	*Median*	*Measures*	r_s	*p*	*N*
Behaviours	Have Eliq Online contributed to changes in everyday behaviours with the aim of reducing energy consumption?	2	3	T1	.102	.678	19
				T2	-.131	.594	19
	Have Eliq Online contributed to purchases of new appliances with the aim of reducing energy consumption?	1	1	T1	.442	.058	19
				T2	-.123	.616	19

Items measured on a 5-point scale with the values 1: Most certainly not, 2: To a low degree, 3: Partly, 4: To a high degree, 5: Most certainly.

In addition to the households' perceived change in behaviours, 13 specific behaviours were analysed in more detail. In general, the households considered that they quite often performed the behaviours in question, resulting in high median values for most behaviours (see Table 5).

To assess the effects of the energy feedback provided on the web portal, potential changes in reported behaviours were assessed short-term and medium-term. A Spearman's Rank Order correlation was run to determine the relationship between the households' use of the web portal and the difference in reported behaviours for the short-term measures (T1 compared to T0) and medium-term measures (T2 compared T0) respectively (see Table 5). No significant correlation between the use-frequency and the 13 measured behaviours could be found.

Table 5. Measured energy related behaviours

Construct	Items	T0	T1	T2	Spearman's correlation			
		Median	*Median*	*Median*	*Measures*	r_s	*p*	*N*
Behaviours	How often do you turn the lights off in unoccupied rooms?	4	4	4	T1 - T0	-.053	.828	19
					T2 - T0	-.348	.145	19
	How often do you buy LED-light bulbs when you need to replace broken bulbs?	4	5	5	T1 - T0	-.286	.236	19
					T2 - T0	-.153	.533	19
	How often do you adjust the indoor temperature according to your needs?	4	4	4	T1 - T0	.039	.876	19
					T2 - T0	.384	.116	18
	How often do you lower the indoor temperature when you leave the house for the weekend or longer?	3	3	2	T1 - T0	-.012	.962	18
					T2 - T0	-.100	.684	19
	How often do you defrost your freezer when needed?	5	5	5	T1 - T0	.139	.595	17
					T2 - T0	.079	.780	15
	How often do you wait for food leftovers to cool down before putting them in the fridge?	4	4	4	T1 - T0	-.010	.967	19
					T2 - T0	-.029	.906	19
	How often do you use a lid when boiling water on the stove?	5	5	5	T1 - T0	-.379	.109	19
					T2 - T0	-.450	.053	19
	How often do you fill the washing machine completely when doing laundry?	4	4	4	T1 - T0	-.430	.066	19
					T2 - T0	-.298	.216	19
	How often do you use the tumble dryer to dry laundry?	3	4	3	T1 - T0	.346	.174	17
					T2 - T0	.033	.895	18
	How often do you turn the TA/VCR/DVD/Stereo off instead of using the standby mode?	2	2	2	T1 - T0	.413	.089	18
					T2 - T0	.157	.533	18
	How often do you unplug your phone charger from the socket when not in use?	4	5	4	T1 - T0	-.042	.867	18
					T2 - T0	.033	.893	19
	How often do you keep the TV off when no one is in the room?	4	4	4	T1 - T0	-.232	.339	19
					T2 - T0	-.157	.521	19
	How often do you turn electronic equipment off completely when you leave the house?	4	5	3	T1 - T0	.083	.737	19
					T2 - T0	.036	.882	19

Items measured on a 5-point scale with the values 1: Never, 2: Rarely, 3: Half of the times, 4: Often, 5: Always/Every time.

Several households reflected on why they had not managed to change behaviours during the study. One participant mentioned her family's life situation as a cause: "*Since we moved to our house four years ago, we have been actively working to reduce our energy consumption. Our second daughter arrived first of March, which meant that the whole family has been at home the last couple of weeks. Consequently, we have run tremendously many more washings of clothes and tableware, cooked more food at home, and used the shower* *more often. I'm afraid our focus has therefore not really been to reduce our energy consumption.*" (Female, age 35). Another participant talked about his engagement for energy conservation and explained that the savings he already had accomplished made further reductions difficult: "*I have worked with energy conservation a long time. We have reduced our consumption by 50% since we built the house in 1995. We have invested in new appliances and heating systems but we have now come to the end of the road.*" (Male, age 63).

4.3 Attitudes and self-efficacy

Prior to the study (at T0), most of the 19 households, which completed the surveys agreed with the statements "*It is important to not use energy without cause*" and that "*A better environment starts with ourselves*" (see Table 6). Some were unsure of how their actions influenced their energy consumption and some felt that they lacked the ability to reduce their consumption. Despite the overall positive environmental attitudes, no correlation was found between the households' use of the web portal during the test period and any of the initial attitudes or the self-efficacy items (at T0). This suggests that households with initial positive attitudes and opinions regarding their capability of reducing their consumption did not use the web portal to any higher extent than the households with less positive attitudes.

Table 6. Attitudes and perceived self-efficacy

Construct	Items	T0	T1	T2	Spearman's correlation			
		Median	*Median*	*Median*	*Measures*	r_s	*p*	*N*
Attitudes	It is important to not use energy without cause.	5	4	5	T1 - T0	-.171	.483	19
					T2 - T0	.069	.779	19
	A better environment starts with ourselves.	5	5	5	T1 - T0	.291	.226	19
					T2 - T0	.194	.426	19
Self-efficacy	A reduction of our energy consumption would reduce our quality of life.	2	2	2	T1 - T0	.281	.243	19
					T2 - T0	.595**	.007	19
	I believe that we are able to reduce our energy consumption.	2	4	4	T1 - T0	.293	.223	19
					T2 - T0	-.247	.309	19
	I am uncertain of our actions' effect on our energy consumption.	2	2	2	T1 - T0	.322	.179	19
					T2 - T0	.433	.064	19

Items measured on a 5-point scale with the values 1: Strongly disagree, 2: Mildly disagree, 3: Unsure, 4: Mildly agree, 5: Strongly agree.
Note: ** indicates a significant difference over time at $p < 0.01$.

To assess the effects of the energy feedback on the households' attitudes and self-efficacy opinions short-term and medium-term effects were analysed. A Spearman's Rank Order correlation was run to determine the relationship between the households' use of the web portal and the difference in reported ratings for the short-term measures (T1 compared to T0) and medium-term measures (T2 compared T0) respectively. Only one significant correlation between use-frequency and changes in attitudes over time was found. There was a strong, positive correlation between the households' use-frequency and increased agreement with the statement: "*A reduction of our energy consumption would reduce our quality of life*". The correlation was statistically significant for the medium-term measurement ($r_s(17) = .595$, $p = .007$). This indicates a possible shift in opinion amongst the households that used the web portal frequently; they found it more difficult to continue reducing their consumption over time without compromising their quality of life. This implies that the households that frequently used the web portal and managed to reduce their consumption, as mentioned in 4.2, initiated acceptable changes during the test period but did not feel that they were able to instigate any additional measures later on.

4.4 Additional effects

To assess additional effects of the energy feedback system, the 19 households were asked whether or not the system had increased their motivation, knowledge, locus of control, and/or behavioural intention. Two months into the study, the majority of households stated that the system had, to at least some degree, increased their motivation, knowledge, and locus of control. Some households expressed that they felt empowered even though their use of the web portal was limited. One participant stated for instance: "*I actually consider the web portal fantastic. Unfortunately, we have not used it to the extent that it deserves to, due to time limitations and lack of motivation. I also try to avoid computers during my spare time. However, I have become generally more aware about my decisions when it comes to energy consumption.*" (Female, age 48). The households that frequently used the web portal reported a marginally higher increase of motivation, knowledge, and locus of control than the other households. However, no significant correlation between the participants' agreement with statements and the households' use-frequency could be observed for T1 or T2 (see Table 7).

Table 7. Perceived motivation, knowledge, locus of control, and intention

Construct	Items	T1	T2	Spearman's correlation			
		Median	*Median*	*Measures*	r_s	*p*	*N*
Motivation	Have Eliq Online increased your motivation to reduce your energy consumption?	2	3	T1	.091	.712	19
				T2	.140	.569	19
	Have Eliq Online reduced your motivation to reduce your energy consumption?	1	1	T1	-.271	.263	19
				T2	.087	.725	19
Knowledge	Have Eliq Online increased your understanding of which everyday behaviours that influence your energy consumption the most?	3	3	T1	.251	.300	19
				T2	.146	.551	19
	Have Eliq Online facilitated conscious decisions to reduce energy consumption?	2	3	T1	.185	.449	19
				T2	.255	.292	19
Locus of control	Have Eliq Online increased your possibility to actively influence your energy consumption?	3	3	T1	.235	.333	19
				T2	.237	.329	19
Intention	Do you intend to change everyday behaviours with the aim of reducing energy consumption?	2	2	T1	.194	.427	19
				T2	-.229	.346	19
	Do you intend to buy new appliances with the aim of reducing energy consumption?	1	2	T1	.248	.306	19
				T2	.005	.985	19

Items measured on a 5-point scale with the values 1: Most certainly not, 2: To a low degree, 3: Partly, 4: To a high degree, 5: Most certainly.

There could be many possible causes for the low ratings, and the participants elaborated on a few of them in the surveys. Several households indicated that they had not been able to report higher ratings, since their level of e.g. motivation and knowledge was high already at the start of the study. One participant wrote: "*Since we already are aware about our energy consumption and its environmental impact, Eliq Online has not influenced us that much. However, I believe that it has great potential for households that are not already enlightened.*" (Female, age 35). Furthermore, several households identified different shortcoming of the system as delimiting factors to why they had not been able to learn more about energy savings based on the feedback provided. One participant suggested that more detailed feedback should be provided: "*We are interested in reducing our energy consumption but would like to see more detailed information and particularly also the environmental impact.*" (Female, age 48), while another participant requested more general information: "*More background information should be included e.g. regarding when it is important to keep the consumption and environmental impact down and why, e.g. information on cold peaks, when spare power is used. A bit of information would increase the understanding of the problem.*" (Female, age 44).

The households' intention regarding future curtailment and investment behaviours were also assessed at T1 and T2 (see Table 7). Some households reported that they, to at least a low degree, had intentions to both change everyday behaviours and buy new appliances with the aim of reducing their energy consumption. Households with high use-frequency reported stronger intentions to engage in curtailment and investment behaviours than the other households, but no significant correlation between intentions and use-frequency were observed for T1 or T2. However, not everyone felt that they could curtail use or invest in efficient technologies even if they would have liked to. One of the households with high use-frequency and very positive attitudes in regards to energy conservation explained her situation at the end of the study: "*A radical change is needed to reduce my energy consumption further, e.g. changing the direct electrical heating to, for* *instance, geothermal heating. Buying a new fridge and freezer. But I have no financial means to do so now.*" (Female, age 58).

5. Discussion

The field test faced different limitations. To avoid participation fatigue, the number of items measuring the effects of energy feedback on relevant constructs had to be restricted, resulting in simplifications of the constructs, and fewer constructs and behaviours than desired were measured. As the study focused on collecting mainly quantitative data, the results do not reflect the magnitude of factors influencing the households' consumption, or the perceived benefits of the energy feedback system in regards to activities of daily life. Moreover, the number of available measuring devices for the energy feedback system limited the number of participating households and the funding for the project restricted the duration of the test period. With a limited number of participants and data for a limited test period, it is difficult to generalize the results. Nevertheless, as few studies have assessed the effects of energy feedback devices on electricity consumption for longer periods than five months or not been able to report sustained effects during follow-up tests (Abrahamse et al., 2005; Van Dam et al., 2010), it is still valuable to discuss the effects of energy feedback on electricity consumption observed in this study, i.e. during the six months test period and the six months follow-up period.

The level of energy savings for the households with high use-frequency is in line with the results observed in other studies (see e.g. Abrahamse et al., 2005; Darby, 2006; Fischer, 2008). The detected correlation between use-frequency and changes in electricity consumption suggests the households frequently accessing the web portal and potentially receiving energy feedback regularly, managed to reduce their electricity consumption to a higher extent than the other households. It can thus be argued that no changes in consumption can be anticipated if the feedback system is not utilized and the feedback information not accessed. However, the observed correlation does not necessarily prove that a causal relationship between use-frequency and reduction in electricity consumption exists. Some factors have yet not been controlled for, which could have had an effect on the results. The calculated energy savings have for instance not been weather-corrected and as some, but not all, of the participating households had direct electric heating systems, the results could be misleading. Nevertheless, the positive effects of the web portal perceived by the households, suggest that the web portal at least to some degree influenced their energy consumption during the study.

As no significant correlations between use-frequency and specific behaviours were observed, previously reported effects of feedback on behaviours could not be detected, such as changes in e.g. lighting behaviours (Abrahamse et al., 2007; Grønhøj and Thøgersen, 2011), changes in behaviours related to energy intensive appliances (Abrahamse et al., 2007; Grønhøj and Thøgersen, 2011; Hargreaves et al., 2010; Wallenborn et al., 2011), and changes in behaviours related to heating (Abrahamse et al., 2007). Moreover, the study shows no correlation between the households' use-frequency and the households' initial environmental attitudes and perceived self-efficacy. Neither were any correlations between the use-frequency and changes in attitudes or self-efficacy detected over time. The findings could thus not statistically confirm the conclusion drawn by Grønhøj and Thøgersen (2011) that providing energy feedback through a feedback display increases householders' self-efficacy.

One possible reason to why few changes in behaviour, attitudes or self-efficacy were reported, could be that the households already prior to the study considered that they quite often performed the behaviours in question or agreed to the assessed statements. The households' ratings resulted in high median values for most behaviours and attitude statements for all three surveys, and few differences were observed. Several households reflected on this and regarded themselves as unable to reduce their consumption much further as they had made many changes already prior to the study. The households also elaborated on several factors that had limited their potential to reduce their electricity consumption further e.g. their family situation, their financial means, and their ability to influence the outcomes of their energy savings actions. This indicates that not all households felt that they had the physical possibility to engage in energy conservation. Niemeyer (2010) identified similar barriers when exploring consumers' adoption of energy-efficient practices. The observed delimiting factors supports previous suggestions that contextual forces and personal capabilities should be considered as causal variables in addition to attitudinal factors, and habits and routines (Steg and Vlek, 2009; Stern, 2000).

The households' perception of their quality of life also seemed to limit their energy conservation efforts. Some found it gradually more difficult to attain energy savings without compromising their quality of life. These findings are in line with Gatersleben (2001), who found that people do not mind minor changes to reduce energy consumption as long as they do not need to make reductions that could compromise their comfort, freedom, and pleasure. Similarly, Hargreaves et al. (2010) also found quality of life related factors to influence people's willingness to reduce their consumption.

Despite the mentioned limiting factors, the households' ratings and reflections indicate that many, regardless of their use-frequency, have experienced positive effects of using the web portal. Some specifically expressed an increased knowledge and awareness, which empowered them to reduce their energy consumption and change behaviour to some degree. The energy feedback thus seems to have sparked learning processes for some households during the study, results that are in line with earlier conclusions on energy feedback monitors (Grønhøj and Thøgersen, 2011; Hargreaves et al., 2010; Wallenborn et al., 2011). However, similarly to the findings of Van Dam et al. (2010), some households found it difficult to interpret the energy feedback, which reduced the learning outcome. The difficulty to interpret the information online could partly be attributed to aspects that concern the design of the feedback interface, such as the functionality, graphical layout, and the terminology used. To improve the learning outcome, the feedback system could, for instance, be developed to further enable the users to relate to the information by providing more personalised and detailed feedback or by enabling the users to more easily analyse the effects of their actions on their electricity consumption. Previous work has shown that appliance specific feedback with personalized tips regarding energy savings measures has been more effective and more appreciated by some households (Fischer, 2008) than aggregated data.

The findings indicate that energy feedback will only be beneficial for those who use the system, embrace the feedback, are willing to reconsider their energy consumption and related behaviours, and furthermore have the economical ability and capability to change their situation. This study thus supports previous findings that energy feedback will most likely not contribute to overall energy savings for all types of households (Van Dam et al., 2012; Wallenborn et al., 2011). As feedback is only one of many intervention strategies suggested to influence energy conservation (cf. e.g. Steg and Vlek, 2009), other strategies could be considered in order to explore ways of enabling more people to reduce their energy consumption. Even though feedback can enlighten people and provide incentives for energy conservation it cannot change the contextual circumstances that govern people's energy consumption. However, changing contextual factors by means of structural strategies could, in contrast, enable and support people to engage in energy saving measures.

6. Conclusions

This study have highlighted the effects and perceived user benefits of online interactive energy feedback. The households that frequently accessed the energy feedback managed to reduce their electricity consumption by an average of 9% over the six-months test period. In addition, they reported slight changes in perceived curtailment and investment behaviours, motivation, and knowledge. Several factors were, however, identified to limit or discourage energy savings, e.g. the users' perception of quality of life, their previous engagement in energy conservation and the magnitude of already accomplished savings. The findings thus suggest that many different aspects such as contextual factors and personal capabilities influence households' energy consumption and that access to energy feedback does not per se lead to savings. Nevertheless, people that utilize the feedback information and are willing and capable of changing their situation can reduce their consumption and gain additional benefits that support energy conservation.

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