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Consumer preferences for feedback on household electricity consumption

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ABSTRACT

Numerous studies have shown that feedback on energy consumption can work to effectively reduce household energy consumption. However, relatively little work has been done on the best ways to present information in order to maximise energy savings. In this work, different ways of presenting feedback on electricity consumption were systematically analysed and user interface prototypes were developed based on the analysis. The prototypes were shown to consumers in qualitative interviews to gain information on how well they understood them and what kind of feedback they prefer to receive on their electricity consumption. The results show that the following features of feedback on electricity consumption are most valued by consumers: presentations of costs (over a period of time), appliance-specific breakdown, i.e. information on what proportion is consumed by each appliance, and historical comparison, i.e. comparison with their own prior consumption.

1. Introduction

Although many studies have shown (see reviews [1–3]) that feedback can work effectively in reducing household energy consumption, consumers typically have very limited possibilities to monitor their consumption. Energy meters are read monthly or yearly and not every consumer has access to their own energy meter. If energy meters are read yearly, monthly bills are based on estimated consumption, i.e. consumption from the previous year. A household receives an additional bill or is paid after the meters are read. Kempton and Layne [4] compared the monthly reading of energy meters to a grocery store without prices: "Consider groceries in a hypothetical store totally without price markings, billed via a monthly statement like 'US$527 for 2362 food units in April'.

A large interview study performed in Finland [5] showed that 63% of people think that it is very important or important to improve the possibility of monitoring energy consumption at home. Only 6% think that it is not important at all.

Changes in legislation (particularly the EU energy directive [6]) and technological development (especially remote real time reading of energy meters) will improve our opportunities to monitor consumption. However, care must be taken when choosing the information the consumers are given and with the way in which it is presented. Essentially, it is important that the information provided to consumers is relevant and enables them to make sustainable decisions about their energy use. The principal purpose of the paper is to study what kind electricity consumption feedback consumers understand and prefer.

2. Feedback on household electricity use

2.1. Energy saving by means of feedback

Numerous studies have shown that feedback can effectively reduce household energy consumption. It is also clear that the savings are dependent on the type and quality of the feedback.

Darby [2] divides the different types of feedback into three main groups: direct feedback, indirect feedback and inadvertent feedback. Direct feedback includes self-meter-reading and interactive feedback via a personal computer or an in-house display. Indirect feedback refers to improved billing, such as more frequent bills based on meter readings and frequent bills including historical or normative feedback. Inadvertent feedback refers to learning by association. This can happen, for example, when new electrical equipment is acquired or when the home becomes a power generation site due to the installation of a solar water collector, a photovoltaic array or a small wind power generator.

Darby [2] presents a review of savings demonstrated by a total of 38 feedback studies worldwide. She concludes that direct feedback, alone or in combination with other factors, is the most effective

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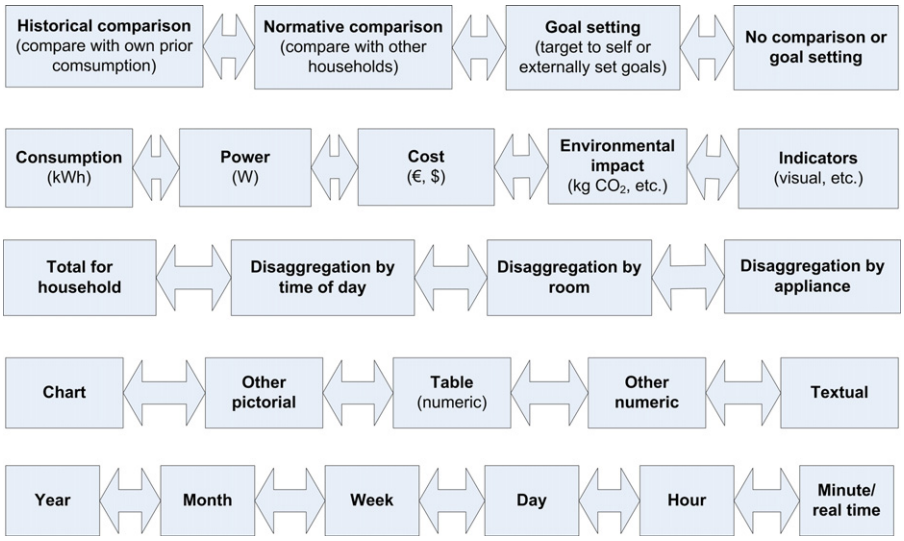

Fig. 1. Summary of options for presenting feedback on household electricity consumption (partly after [8]).

single type. In most of the studies that include direct feedback the savings were between 5 and 20% while indirect feedback resulted in lower savings. Only three of the studies included inadvertent feedback, so typical savings are not known, but, according to Darby, it is likely that people who generate their own power pay more attention to their energy use and change their way of thinking. In a later review on feedback studies, Fischer [1] concludes that the most effective feedback uses computerized and interactive tools for engaging households in reducing energy consumption.

Unfortunately, most papers fail to present in detail the feedback given to the consumers in the studies. The reasons for choosing a specific design are not discussed, as stated by Fischer [1]. The following section discusses alternative ways of presenting feedback and their potential effect on energy consumption.

2.2. Alternative ways of presenting feedback

In this section different ways of presenting feedback will be systematically analysed. The goal is to evaluate the potential energy conservation effect that different kinds of feedback on energy consumption may have. The analysis concentrates on direct feedback, which takes the form of interactive feedback via a smart meter, in-house display or personal computer. The analysis does not involve energy bills although they may provide a similar kind of feedback.

Fig. 1 shows the main alternatives for household energy feedback.

2.2.1. Comparisons

2.2.1.1. Historical comparison. Consumers may be motivated to save energy if they can compare their consumption to their own prior consumption or to the consumption of others. Historical comparison, i.e. comparison with the household's prior consumption is a common way of presenting energy feedback. Historical comparison is available in almost all energy monitoring solutions. According to Roberts and Baker [7], consumers are able to interpret historical comparative information.

If weather has an effect on consumption, normalised (weather compensated) consumptions instead of absolute consumptions should be compared. Unfortunately, it is very common to show consumers only the absolute values, although they are often not valid for historical comparison. For example, electricity consumption may be largely affected by the weather, if electricity is used for space heating, which is common in single-family houses in some countries, like Finland. Monthly consumption comparisons do not replace the need for weather compensation since they only take into account the season and not the weather differences between the years.

2.2.1.2. Normative comparison. Another type of comparison is to compare own consumption with that of others. Household consumption can be compared at a national or regional level, or even within a neighbourhood. The comparison data could be received from a data bank. The more similar the compared households are the more relevant the information provided by the comparison, since there are a lot of building and household characteristics that significantly affect consumption, e.g. year of construction, floor area, number of occupants (adults and children) and climate conditions. Roberts and Baker [7] state that people are motivated to reduce consumption if comparisons show them to be "above average for a group they perceive to be relevant for comparison".

If comparisons show that their own consumption is below average, are consumers still motivated to reduce their consumption? They may feel they have done enough and see no need to change their behaviour even if there is still plenty of potential to reduce consumption. An important question is how to engage those people in energy conservation. They could be rewarded in some way, for example, by giving them a sort of virtual reward. They could reach an "advanced level" with new features in the energy feedback software (in the same way as new levels are unlocked in computer games). It is not known how effective these kinds of software features are in engaging consumers in energy conservation.

People may also be good at justifying their own energy related behaviour in situations where their consumption is found to be higher than average. They may think that there is a good reason for high consumption. 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. Another may find other reasons for high consumption, whether they are real or not. To avoid erroneous impressions consumers would need information on which household appliances consume the most energy.

2.2.2. Goal setting

Consumers may be motivated to save energy if they have a goal to aim at. For example, a household could have a goal to reduce electricity consumption by 20% compared to the previous month. The

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target could be set from outside the household, or the household could set the goal themselves.

An important question is how to set a goal that is effective and that leads to energy conservation. The target level of consumption should not be so low that it is impossible to reach. Conversely, if the target consumption is on the high side and very easy to reach, it does not provide motivation to save energy. The same percentage target value is not suitable for all households since there are currently large differences between households in terms of energy-related behaviour. Some households have a very limited potential for savings, whereas in others the savings potential is very high. For those households that consume more than average, a reasonable goal would be to aim not to consume more than consumed on average by similar households.

When consumers are given an energy saving goal they should also be given advice on how to change their behaviour in order to reach their energy saving goal in the most effective manner. It is also important that they have tools to monitor their consumption during the period they attempt to meet the target. Households should receive positive feedback or rewards for improving their energy-related behaviour.

2.2.3. Presenting consumption, power, cost and environmental impact information

Information on energy use can be presented using many different units (second row in Fig. 1). An obvious presentation method is to use kilowatt-hours (kWh) as seen on energy bills. 1 kWh of electricity is consumed if an appliance operating at 100 W is used for 10 h or an appliance operating at 1000 W is used for an hour. Unfortunately, people have a very limited understanding of scientific units [8]. Although the calculations above show that kWh is a unit that is directly related to power (W) and operation time (h) and that consumed energy is easy to calculate from these two values, people are largely unfamiliar with kWh. Instead of kWh, energy consumption could be presented in J (1 kWh = 3600 kJ) but it is not a wise idea to make this change, as people are more familiar with kWh being used to present household energy use.

It is clear that people are more familiar with monetary units (of their own currency; €, $, £, etc.) than with scientific units. If the ultimate purpose of saving energy is to reduce costs, it is sensible to present the consumption and savings using a monetary unit. If tariffs are not constant throughout the day and week but change depending on a fixed or variable schedule, it is even more important that households are informed of their energy costs.

Providing information about household electricity costs may lead to more efficient energy conservation than showing consumption in kWh. However, if electricity costs are low compared to family income and other household costs (for example, other housing costs, gasoline, food, etc.), information on electricity costs may decrease rather than increase interest in saving energy.

Information on energy use can be presented in the form of environmental impact (for example, carbon dioxide emissions in kg). This is a natural way presentation method, considering that the principal purpose of energy conservation is to reduce greenhouse gas emissions. Because environmental impact depends on the energy source as well as kWh, this presentation method is valuable for understanding the environmental effects of own energy use. However, people are still largely unfamiliar with environmental impact presentations and, for example, cannot even roughly estimate how much carbon dioxide is emitted by a typical household every month due to electricity usage. This means that environmental impact should be presented along with some kind of comparative data that gives an idea of relative emission levels.

The real-time presentation of electric power (in W) can give consumers valuable insight into their energy use. They can switch appliances on and off and see the effect this has on the total power. If they switch all appliances off they become aware of combined standby power, which may be surprisingly high. Instead of, or in addition to W, real-time information on energy use can be presented in other units such as €/h or kg-CO_2/h.

Different kinds of visual presentations have been designed to illustrate energy consumption. For example, Power Flower by Andy Best (the winner of a design competition arranged by a large energy company, Helsingin Energia) shows a flower that changes shape and colour depending on energy use. When real time energy consumption is low, the flower has an intense colour and the petals are large. In a situation where consumption is high the petals are scattered and dull in colour, indicating a dead flower. When a medium amount of energy is being used, the flower has intermediate characters. These kinds of simple indicators do not deliver accurate or detailed information but they do draw attention and promote energy saving. In households, consumers need more information on their energy use than a simplistic indicator alone can deliver.

2.2.4. Disaggregations

Energy meters typically only show a household's total consumption, which is not disaggregated in any way. Some sort of disaggregation can give consumers a deeper insight into household energy use. A breakdown could be provided by time of day, by room or by appliance [1].

A disaggregation by times of the day and week may be particularly appreciated by those consumers whose energy use is charged based on a time- and week-dependent tariff schedule. A disaggregation by room may provide useful information on where most energy is used.

A disaggregation by appliance provides insight into how much each appliance in the household consumed in the past or currently consumes. An appliance-specific breakdown has the potential to deliver valuable information to help people understand the relevance of individual actions, so they can make sustainable decisions about their own energy use. Consumers do not currently have a good knowledge of the proportional consumption of each appliance. In her review of feedback studies, Fischer [1] concludes that designs which provide detailed, appliance-specific breakdown are linked to the achievement of the greatest savings.

2.2.5. Graphical, numeric and textual presentations

It is clear that the method used to present household energy consumption information affects how the data is understood and the attractiveness of the system. This in turn – presumably – has a significant effect on achieved energy savings. However, there is a lack of studies that consider the issues of how to present energy consumption feedback [1]. The scarce information that is available concerns mostly bill design instead of the design of interactive systems.

A focus group study [7] on bill design came to the following conclusions:

- The information should be simple (but not simplistic) with a robust and credible basis.
- A combination of text, diagrams and tables was found to work more effectively than single-format presentations.
- Graphical presentations were favoured but text labels were needed to assist understanding.
- Presentation should not involve considerable additional paper (seen as wasteful).

In a study that targeted energy saving by improving bill design [9] it was found that consumers paid more attention to graphic presentations than textual presentations. A bar chart presenting a historical comparison and a pie chart showing the proportions

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of day- and night-time consumption were found to attract more attention than the textual presentations of kWh, costs and saving tips.

Wood and Newborough [8] found no studies in the literature that compare numerical and graphical presentations of energy consumption data on local displays. There are, however, general human-computer interaction guidelines available. Perhaps the most detailed guidelines are provided by Smith and Mosier [10].

Smith and Mosier have created a large set of guidelines for the design of user interface software. One of their six functional areas is data display. The following list summarises some of their guidelines that are relevant to energy consumption feedback.

- Provide only necessary and immediately usable data; do not overload displays with extraneous data.
- Display data in a directly usable form; do not make users convert displayed data.
- Display data consistently with standards and conventions familiar to users.
- For displayed data and labels, choose words carefully and then use them consistently.
- Provide a clear visual definition of data fields, so that the data are distinct from labels and other display features.
- When information handling requires a detailed comparison of ordered sets of data, adopt a tabular format for data display.
- Consider graphics rather than text description or tabulation, to display data showing relations in space or time (for example, trends).
- Consider a pie chart only in special cases to show the relative distribution of data among categories, i.e. for displaying data that represents proportional parts of a whole; but note that a bar graph will permit more accurate interpretation for such applications.

2.2.6. Time scale

Energy consumption information (for example, kWh, average W, €, kg-CO_2) can be provided on yearly, monthly, weekly, daily or hourly basis. Preferably, the consumer has the chance to choose the time period of interest. In addition, real time values (for example, W, €/h or kg-CO_2/h) can be shown if the system is capable of real time measurement.

2.2.7. Other

Social rewards can be used to motivate people to save energy. There are solutions currently available that enable people to upload their consumption data to the internet. Good energy saving results may gain appreciation from others. The data can be anonymous or not.

An energy monitoring solution can provide a feedforward to show what consequences particular behaviours will have [11]. For example, consumers can be informed how long it takes to consume 10 000 kWh or 1000 € with their current energy use behaviour.

2.3. Purpose of the study

Energy consumption feedback can be presented in various forms as shown above. However, there is little information available on what kind of feedback households prefer and what kind of feedback works most effectively in reducing household energy consumption. In her review Fischer [1] concludes that feedback has to capture the consumer's attention, activate various motives and link specific actions to their effects. She says that the most successful feedback combines the following features: it is given frequently and over a long time, it provides an appliance-specific breakdown, it is presented in a clear and appealing way and it uses computerized and interactive tools.

Roberts and Baker [7] see that the manner of presentation has been largely overlooked in the literature and note that "there is relatively little work done on the best ways to present information to consumers in order to *maximise* these benefits". Wood and Newborough [8] see that little is known about how best to indicate energy use and energy saving on a display, especially at the level of an individual activity and appliance. Roberts and Baker [7] found evidence to suggest that engaging consumers in the design of energy consumption feedback leads to more effective designs.

In this work, a user-centred perspective is taken in order to study what kind of feedback consumers understand and prefer.

3. Methods

3.1. Interviewing

Interviews were performed to study consumer attitudes to energy monitoring and especially to find out what kind of electricity consumption feedback consumers understand and prefer. Part of the interviews involved showing participants user interface prototypes to illustrate some possible alternatives for providing electricity consumption feedback (see the next section). The prototypes were shown in the middle of the interviews, so further interview questions were posed after the participants had seen the prototypes.

The interviews were semi-structured: not all the questions were designed and phrased beforehand, but many questions were created during the interview, allowing for flexible discussion. In contrast, some of the questions were answered with a constant scale from 1 to 5.

A total of 14 interviews were carried out in Finland. The participants were chosen from diverse educational backgrounds, so the study involved people with education levels ranging from basic to university degree. The participants were between 19 and 67 years of age and 4 women and 10 men were interviewed.

The analysis of the interviews consisted of systematically categorising of the interview responses. The categorisations were made for the central issues of the study, including interest in energy saving and monitoring at home.

3.2. Paper prototyping

The idea of the work is to show user interface prototypes to consumers, to gain information on how well they understand them, and to gather their opinions. For this purpose, eight prototypes were developed (Figs. 2 and 3).

The participants were encouraged to think aloud and to comment on the prototypes while exploring them for the first time. They were asked questions to clarify whether they had understood the information presented in the prototypes. The user interfaces were printed on papers so there was no real user interaction with the test prototypes. Paper prototyping [12,13] is a widely used method in the user-centred design of interactive systems.

In the tests, paper prototypes (from 1 to 8) were displayed one at a time. When the participants had seen all the prototypes, they were asked to choose the prototypes they would prefer to use themselves. They were also encouraged to give suggestions on how to improve the prototypes.

The prototypes were carefully designed to be simple and to use the same kinds of graphic design to make them comparable with each other. The electricity consumption data shown in the prototypes represent typical consumptions and costs in Finnish households at the time of the study (partly after [14]). The prototypes were originally in Finnish, but the texts were translated into English for publication. A summary of the information presented in the prototypes is shown in Table 1.

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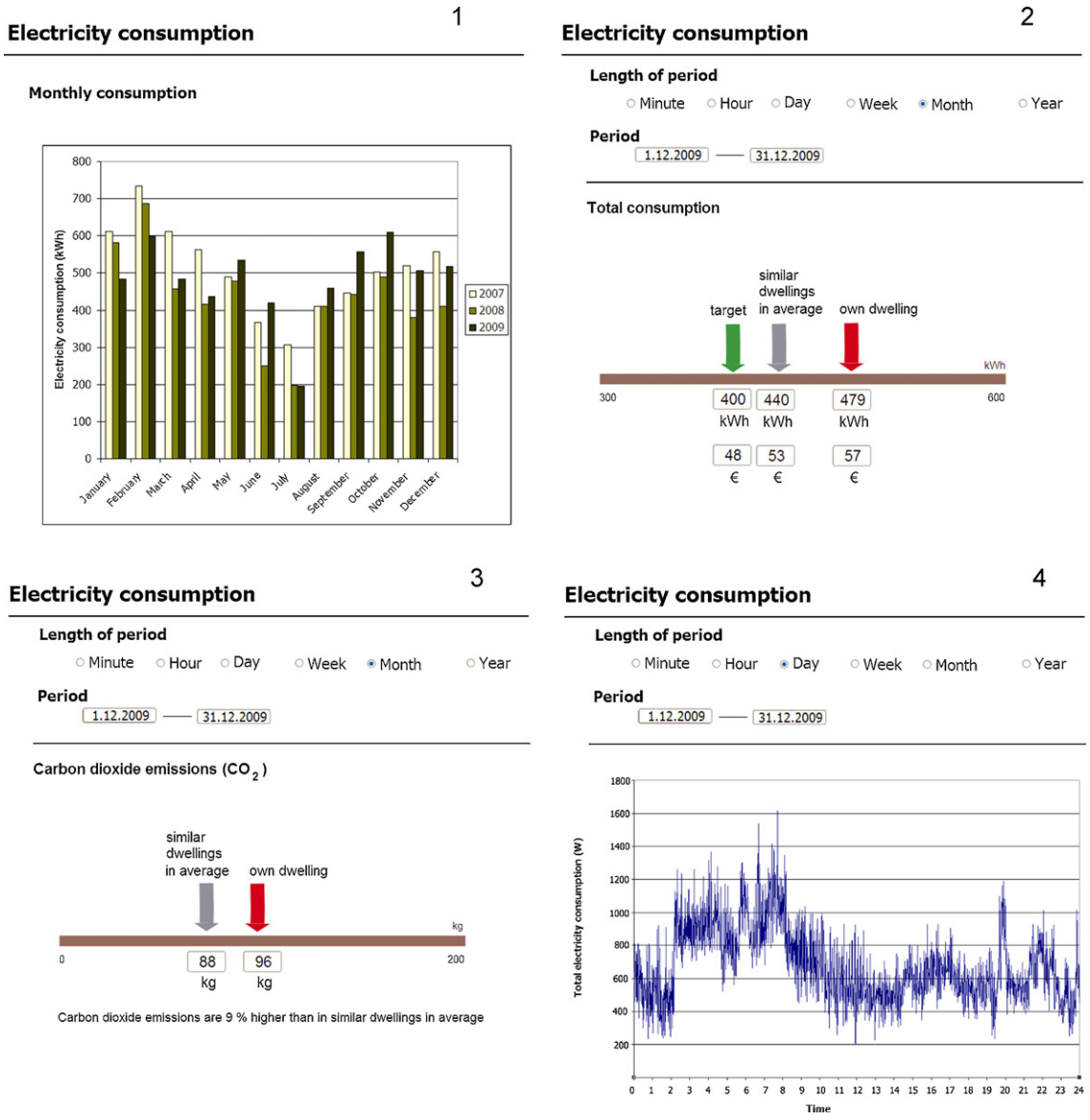

Fig. 2. User interface prototypes 1–4. The design of prototype 2 (and 3) was inspired by [15].

Table 1
Summary of information presented by the prototypes (the classification after Fig. 1).

	Prototype 1	Prototype 2	Prototype 3	Prototype 4	Prototype 5	Prototype 6	Prototype 7	Prototype 8
Historical comparison	•							
Normative comparison		•	•					
Goal setting		•						
No comparison or goal setting					•	•	•	•
Consumption (kWh)	•	•				•	•	•
Power (W)				•	•			
Cost (€)		•				•		
Environmental factor (kg CO_2)			•					
Total for household	•	•	•	•	•	•	•	
Disaggregation by time of day (day- and night-time tariffs)							•	
Disaggregation by appliance					•	•	•	•
Chart	•			•	•		•	•
Other pictorial		•	•					
Table						•		
Other numeric		•	•		•			•
Textual			•					
Chooseable time period (min, h, day, week, month, year)		•	•	•		•	•	•

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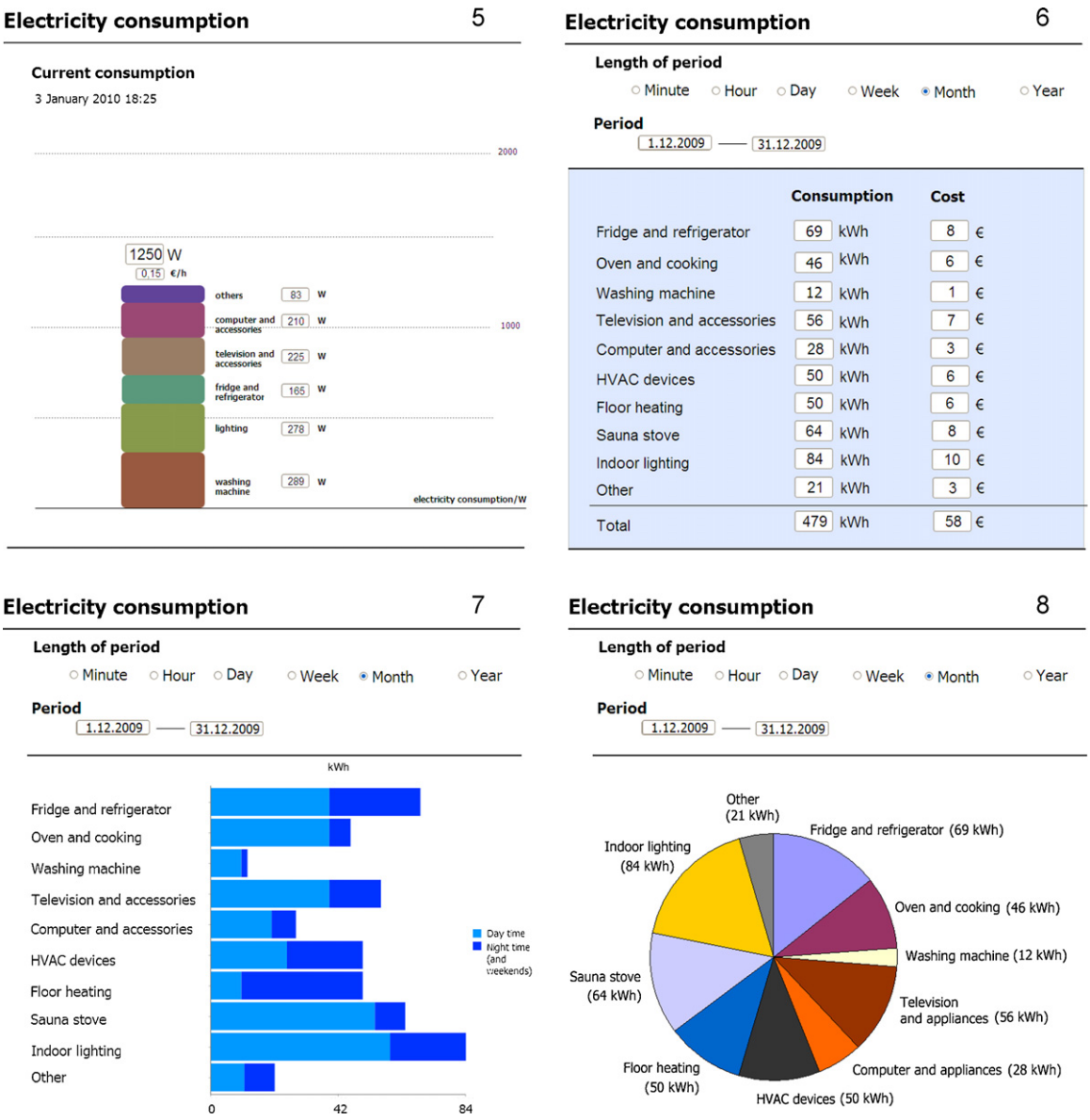

Fig. 3. User interface prototypes 5–8.

4. Results

4.1. Interest in saving energy and receiving feedback on own energy consumption

The qualitative interviews clearly showed that some consumers are very interested in saving household electricity while other consumers show only a little interest. In the interviews consumers were not only asked to describe how active they are in saving energy but they were also asked to list the measures they have taken to save energy. Some respondents listed numerous measures, whereas others just said that they turn lights off in rooms that are empty. Those who take many energy saving measures do not necessary feel that they are active savers and may feel that they could do even more. According to the interviews it seems that interest in saving energy is not only related to levels of environmental awareness but also to a general money-saving attitude. Some respondents mentioned that they are more active energy savers than some other persons in the family. Most of the respondents are not currently able to read their energy meters and receive information about their consumption only once a year from the energy company.

Most Finnish people visit a sauna at least once a week. Some go to the sauna every day. In the countryside most saunas are wood fired, but sauna stoves are electrically heated in densely populated areas. A sauna is heated up to at least 80 °C. In the interviews many people clearly stated that they are not willing to go to the sauna less often to reduce electricity consumption, although they realise that it consumes a lot of energy. In contrast, one of the interviewees stated that they use saunas very rarely to save energy.

Although this is a qualitative study with a small number of respondents, some of the results are shown in numerical form in the following tables. Tables 2 and 3 give an overview of interest in electricity saving and monitoring, how easy bills are to understand, and current knowledge of own electricity consumption. These results clearly show that consumers are interested in energy monitoring and need more information than electricity bills currently provide to make right choices about their energy use.

A very important question is whether the energy saving measures taken in households are effective in reality. Are real savings

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Table 2
Electricity consumption related knowledge of consumers. N = 14.

	Yes	No
Does the interviewee know the household's level of electricity consumption in kWh?	5	9
Does the interviewee know the level of the household's electricity costs in Euros?	7	7

	Average
(A question asked:) How easy is it to understand the information provided on the electricity bill? (5 = very easy, . . ., 1 = very hard)	3.2
(A question asked:) How well does the information provided on the electricity bill state what is worth doing to save electricity in your household? (5 = very well, . . ., 1 = very badly)	2.0

achieved? The real effect caused by energy consumption measures was not studied in this work and no measurements were made, but the issues were discussed in the interviews. It was found that even though people are motivated to save energy, they are short of information that is needed to achieve significant savings. Based on the interviews, it is clear that some of the measures taken to save energy have an insignificant or minor effect. First, people may be seriously concerned about the amount of energy used by appliances that only consume very little in reality. This is especially true for high powered appliances that are only used for short periods of time. For example, if a vacuum cleaner has a power of 1 kW and is used for half an hour a week, its monthly energy consumption is 2 kWh. This constitutes only a very small fraction of overall monthly consumption. Second, in cases where electricity is used for space heating, there is no reason to worry about standby power, etc. during the heating period, since the electricity consumed decreases the need for heating and no additional energy is used. People are commonly unaware of this and take energy saving measures that are ineffective as a result.

Interviewees preferred to receive feedback on their electricity consumption either from a bill, a web-page (personal computer) or a dedicated wall display. None of the respondents preferred to use a mobile phone for monitoring.

4.2. Ease of understanding and consumer preferences about electricity consumption feedback

Most of the prototypes (presented in Figs. 2 and 3) were found to be easy to understand by the participants. The problems with understanding the prototypes mainly involved two issues: (1) many people are not familiar with scientific units and do not understand the difference between W and kWh and (2) many people do not understand how carbon dioxide emissions are related to electricity consumption.

In contrast, people are familiar with different kinds of charts and can easily interpret bar charts and pie charts among others. A tabular presentation (prototype 6) was also found to be quickly and easily understood. Observations and notes on how easily each prototype was understood are shown in Table 4.

After the participants had seen all the prototypes, they were asked to choose between them and to state which of them they would choose for their own use. Clearly the most favoured prototype was number 6. It gives a total overview of consumption and costs with an appliance-specific breakdown. Other findings include the following. People were not interested in receiving information on carbon dioxide emissions. More attention was paid to historical comparisons (comparisons with own prior consumption, prototype 1) than to normative comparisons (comparisons with other households, prototype 2). The results are shown in more detail in Table 5.

After the participants had seen the prototypes they were asked some additional questions. The results presented in Table 6 are consistent with the findings from examining the prototypes, i.e. consumers are more interested in historical than normative comparisons, and are interested in receiving information on the electricity consumed by single appliances.

Most respondents were interested in receiving information about how much energy is consumed by each appliance in the household (Table 6). Least interest was shown by those whose current electricity consumption and costs are low. They believe that improved energy consumption feedback only has a low potential for saving energy.

In summary, the following features of electricity consumption feedback were found to be most valued by consumers:

- presentations of costs (over a period of time),
- appliance-specific breakdown, i.e. information on how much each appliance consumes proportionally,
- historical comparison, i.e. comparison with own prior consumption.

Presentations showing the amount of electricity consumed (kWh) are more useful for consumers than presentations of power (W), since they do not just give instant values but show the consequences of particular behaviour over a period of time. Since consumers do not have a good idea of the proportional consumption of their appliances, an appliance-specific breakdown is helpful for understanding the relevance of individual actions.

The consumption of single appliances (or groups of appliances, e.g. computer with accessories) can be presented in various forms, as shown by the examples of the prototypes. A tabular presentation was favoured over the others by the interviewees, but charts can also be used for this purpose. However, pie charts may not be suitable for the purpose, because, first, there are too many appliances

Table 3
Consumer interest in saving electricity and monitoring consumption, *N* = 14.

	Yes	No
Does the interviewee actively try to save electricity at home?	8	6
Does the interviewee want to monitor electricity consumption?	14	0

	Average
(A question asked:) How much do you try to save electricity at home? (5 = very much, . . ., 1 = very little)	3.0
(A question asked:) How important is it to improve the possibilities for monitoring electricity consumption at home? (5 = very important, . . ., 1 = not important at all)	4.3

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Table 4
Understandability of the information presented in the prototypes.

	How many of the total of 14 participants understood the information presented in the prototype?	Observations and other notes
Prototype 1	14	Information presented in the bar charts was easy to understand. After a short examination all of the participants were able to compare differences in monthly consumption over the years. Many people currently receive similar information on their electricity bills but typically only yearly consumption is shown and people are unaware of their monthly consumption. People are familiar with bar charts since they are commonly used for presenting various data. One of the participants works as a bus driver. He noticed that gasoline consumption is monitored with a similar kind of chart.
Prototype 2	14	The participants did easily understand the meaning of the presentation, i.e. they noticed that own consumption is higher than the average consumption in similar dwellings and than the target consumption. Some participants noted that the reason for the high consumption remains unclear. Several participants asked about who set the target and how it is calculated. One of the participants noted that the number of inhabitants is not shown and it should be taken into account for setting the goal.
Prototype 3	8	Many participants did not understand what is meant by carbon dioxide emissions, and how these emissions are related to electricity consumption. A common assumption was that the carbon dioxide emissions are only related to the use of fireplaces (or wood-fired saunas). Only a few respondents understood that emissions are related to the energy source (in addition to electricity consumption). If information about the energy source were presented in the user interface, it would make it more understandable.
Prototype 4	12	Most participants understand the purpose of the chart and can use it to recognise the periods of time when consumption is highest. They understand that with a help of the chart they can develop their understanding of how much each appliance consumes. However, it is not easy to make out from the figure what the proportional consumption of each appliance is.
Prototype 5	7	It is easy to see from the texts in the chart that it shows disaggregated consumptions of several appliances. However, the chart was not fully understood since many participants did not understand that the prototype shows power (W) rather than energy (kWh) consumption. The tests were performed with (static) paper prototypes. A real time version would make it easier to understand that the chart only shows current power values (W). The prototype also provides information on the costs per hour (€/h), but this feature received almost no attention from the participants. The value (€/h) is not very illustrative and could be supplemented with a symbol that shows whether the current value is more or less than the household average, as suggested by one of the participants.
Prototype 6	14	The prototype was instantly understood by everyone. The participants noticed that the prototype gives information on both consumption and costs.
Prototype 7	13	Almost everyone understood the information presented in the prototype. In addition to total consumption, the chart gives information on day- and night-time consumption, which was well understood by the participants. That is valuable information for those who have separate day- and night-time tariffs.
Prototype 8	14	All the participants are familiar with pie charts, so they had no problem with understanding the prototype. The pie chart was found to be aesthetically pleasing but several participants noted that the information is presented more clearly in prototype 6. The values presented around the pie received little attention. One of the participants noted that differences between the bars in prototype 7 seem to be large, but in the pie chart the differences are diminished.

Table 5
Consumer preferences for the prototypes. Number of participants: 14.

	Number of participants who preferred the prototype over all the other prototypes	Number of participants who rated the prototype in second or third place (not everyone chose two or three favourites)	Notes
Prototype 1	1	3	Generally liked, a familiar presentation method.
Prototype 2	1	0	Not much interest was shown by the participants.
Prototype 3	0	1	Received almost no interest (a biologist working in nature conservation was the only one interested).
Prototype 4	0	5	Some interest was shown by the participants, not such a clear presentation method as some others.
Prototype 5	1	1	Not needed continuously but could be used once to give information on the power consumed by appliances.
Prototype 6	7	3	Clearly the preferred presentation method. Gives a total overview that can be quickly and easily understood. The appliance-specific breakdown was appreciated. The costs are considered to be very essential information.
Prototype 7	1	4	Clear way of presentation. Information on day- and night-time consumption is of particular interest to many of those who have separate tariffs for day- and night-time. Information about costs would also be needed.
Prototype 8	3	2	Found to be aesthetically pleasing and was favoured by several participants. Some others considered this to be less clear than the previous ones with the same information.

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Table 6
Consumer interest in certain characteristics of electricity consumption feedback. All the questions were answered on a scale from 1 to 5 (1 = not important at all, . . ., 5 = very important), $N = 14$.

	Average
How important is it to be able to compare your household's electricity consumption to other similar households?	3.6
How important is it to be able to compare your household's electricity consumption to your own prior consumption?	4.4
How important is it to have a target level for electricity consumption (the goal is not to consume more)?	3.5
How important is it to know the electricity consumed by single appliances (in addition to the total electricity consumption)?	4.1
How important is it to receive information on actions which would effectively save energy in your household?	3.9

(or appliance groups) in a household to be presented clearly in a pie chart and, second, it is not easy to compare the size of items in a pie chart.

5. Discussion

The prototypes used in this work were designed by a user interface expert. They are simple, are clearly labelled, and only provide the necessary data. The results of the work show that people can easily understand most of the prototypes that were compared. However, it should not be interpreted that consumers understand all or most kinds of energy feedback. The results show that consumers understand several kinds of energy feedback, including various charts if they are well designed.

An obvious target is to create a system that gives consumers understandable information about their energy use. The results of this work do not say how large savings could be achieved with a system that is easy to understand and has characteristics which consumers prefer. However, it may be safe to suppose that savings would be higher than in similar cases where no special attention is paid to the quality of energy use feedback.

The interviews in this work clearly show that some consumers are more interested in energy conservation than others. It is probable that those consumers who are motivated to save (but do not currently have the necessary information on their consumption) would profit most from improved energy use feedback. This does not necessarily mean that the most unreasonable users of energy change their behaviour – not everyone is motivated to do that. The improved energy consumption feedback may work as a motivator to save energy but it may be best to combine a variety of motivators as suggested by McMakin et al. [16].

Consumers prefer to receive information on the costs of their energy use. A goal to reduce energy costs may serve as the principal motivator to save energy. However, it is also possible that showing costs decreases interest in saving energy [8]. This may happen if consumers consider energy costs to be minimal when compared to family income and/or other household costs.

Future work should study the effect of the preferred prototypes on energy consumption in real use. It would be especially valuable to investigate the real-use situation over a longer period of time. Another key challenge would be to study the effects of showing energy costs in the user interface. Does it have positive effect on energy savings in some cases and negative in some other cases?

In this work, understandability and consumer preference of the prototypes were compared. The eight prototypes were chosen to have divergent characteristics. Most typical ways of presenting energy feedback were involved in the study. However, it is clear that many other ways of presentation are possible. For example, none of the prototypes shows hourly use of important appliances in typical days to remind the consumer of paying attention on the usage schedule of the appliances. Neither was forecast consumption (see Section 2.2.7) shown in the prototypes.

Various strategies should be used to motivate all households to save energy. The future development of energy monitoring systems could also seek inspiration from game designs and social media, and the importance of aesthetic design should not be neglected.

6. Conclusions

Consumers – even if they are motivated to save energy – are short of information that they need to make sustainable decisions about their energy use. They do not have a good idea about their consumption and they need more information, especially concerning the proportional consumption of appliances, to make the right choices about their use of energy. An appliance-specific breakdown needs special technology (for example, sub-metering or non-intrusive appliance monitoring) but it has the potential to deliver valuable information to aid understanding of the relevance of individual actions.

Presentations of the amount of electricity consumed (kWh) are more useful for consumers than presentations of power (W), since they do not just give instant values, but also show the consequences of particular behaviour over a period of time.

Regarding the understandability of the electricity consumption feedback the interviews and paper prototyping revealed the following:

- People can interpret various kinds of charts and tabular presentations if they are well designed.
- Many people have problems with understanding scientific units and do not understand the difference between W and kWh.
- Many people do not understand how carbon dioxide emissions are related to electricity consumption but may assume that they are only related to the use of fireplaces.

In summary, the following features of electricity consumption feedback were found to be most valued by consumers:

- presentations of costs (over a period of time),
- appliance-specific breakdown, i.e. information on how much each appliance consumes proportionally,
- historical comparison, i.e. comparison with own prior consumption.

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