



Effects of continuous feedback on households' electricity consumption: Potentials and barriers



Andreas Nilsson^{a,*}, Cecilia Jakobsson Bergstad^a, Liane Thuvander^b, David Andersson^c, Kristin Andersson^a, Pär Meiling^b

^a Department of Psychology, University of Gothenburg, Sweden

^b Department of Architecture, Chalmers University of Technology, Sweden

^c Department of Physical Resource Theory, Chalmers University of Technology, Sweden

HIGHLIGHTS

- Two studies on conservation behaviours using in-home-displays are presented.
- No significant effects on electricity consumption were found.
- Display feedback does not necessarily contribute to lower electricity use.
- Interviews conclude that different types of feedback techniques should be combined.
- Two important barriers are difficulties to understand the display and a lack of interest.

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ABSTRACT

Two field experiments were carried out to study (a) the effects on energy savings of continuous visual feedback via in-home displays, and (b) the motives for responding or not. In study 1, 40 participants living in separate or semi-detached houses in two different towns participated. All participants received a questionnaire and a list of possible energy saving measures. Households were then randomly assigned to an experimental condition (display) or a control condition (no display). In study 2, 32 households in rented apartments participated. No significant differences between the conditions were found for either of the studies. In study 2, semi-structured interviews were conducted among nine of the households. Through an analysis of interview transcripts barriers were identified explaining why the feedback intervention was not sufficient to change behaviour and reduce consumption. The barriers experienced indicate that there is a risk of overconfidence in IHDs. For the development of energy policies and more wide-scale implementation, it is important to be aware of the potential obstacles to success.

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1. Introduction

A large proportion of the world's energy is used by households. The direct energy use by households in the USA (including car transports) accounts for around 38% of total US carbon emissions [1]. In homes, the use of electricity accounts for more than half of the energy consumed, of which the major part concerns air conditioning. In Sweden, about 20% of the total annual consumption of electricity is related to private household electricity use (lighting,

appliances, etc.) [2]. Over the past 30 years, the technical energy efficiency of appliances has improved substantially, while in the same period the domestic electricity demand increased. This can be attributed to an increase in electricity using equipment, for instance kitchen appliances, heat pumps and floor heating [3]. The potential to reduce energy use in most areas is however relatively good. For example, in a recent study [4] the behavioural plasticity (maximum potential for energy reduction through behavioural change) for the use of standby equipment and laundry behaviours is estimated at 35%. Many of these changes in behaviour are also relatively easy for individual households to achieve.

Household energy conservation has been an area of research for applied social and environmental psychology since the oil crises in the 1970s. The results so far have been reviewed a few times over the years [5–7]. This has revealed a picture varying from very

* Corresponding author. Tel.: +46 317861651.

E-mail addresses: andreas.nilsson@psy.gu.se (A. Nilsson), CJB@psy.gu.se (C.J. Bergstad), liane.thuvander@chalmers.se (L. Thuvander), david.andersson@chalmers.se (D. Andersson), kristin.andersson@psy.gu.se (K. Andersson), par.meiling@chalmers.se (P. Meiling).

positive, for example regarding the effectiveness of frequent feedback, to less clear, in terms of the lasting effects of behavioural changes [7]. However, some of these results and conclusions suffer from methodological shortcomings, such as the combining of different types of interventions, making it difficult to discern the independent effect of a single strategy. Previous research is also deficient in terms of the attention to the influence of underlying psychological determinants of energy use and energy savings [7].

The overall aim of the present work is to study the influence of feedback on household electricity consumption and to understand the effects, potentials and barriers to electricity conservation. Several shortcomings from previous studies are addressed in these studies. In previous studies participants often take part as a consequence of their own interest, i.e. have a certain interest in energy issues. When preparing for the wider implementation of continuous feedback systems such as IHDs, it is important to investigate the effect of the feedback among households who do not actively seek to participate, and in that respect can be expected to be more similar to a normal population. Previous studies are also lacking in investigating apartments. Since apartments in general have lower electricity consumption, these households may experience lower motivation to conserve electricity compared to private homes. Another lack in previous studies is in depth interviews following interaction with the IHDs. It is important to investigate experienced barriers after the experimental period, especially if the results show small effects. This is investigated by carrying out two field experiments using continuous feedback intervention via in-home displays (IHDs), and a follow up interview study with participating households. Below a brief overview of central concepts and previous research in this area are presented.

Interventions aimed at encouraging households to reduce energy consumption can be divided into antecedence strategies (i.e. information, commitment, goals, modelling) and consequence strategies (i.e. feedback and rewards). It has been found that information alone tends to result in higher knowledge levels, but not necessarily in changes of behaviour or reduced energy consumption [7]. Instead, information in combination with commitment, commitment alone, modelling (demonstration of the behaviour by others) and goal setting have been found to produce environmentally responsible behaviour [5].

A major obstacle to motivating these types of behavioural changes is that the consequences of the behaviour are delayed. As a result, it is difficult to know which types of behavioural change lead to reductions in energy consumption. In classical psychological learning theory [8], behaviour must be reinforced in order to lead to change. People continue with behaviours that are rewarded, and these rewards are essential to ensuring the repetition of desirable behaviour. The closer in time the consequences of the behaviour are recognised, the greater the impact they will have on the behaviour.

In most feedback intervention studies (see Abrahamse et al. [7] for a more comprehensive review), the feedback contains information about the energy consumption of the households in terms of energy units and/or monetary values. A distinction is made between continuous feedback, in most cases using a monitor or display showing the current consumption; and daily, weekly or monthly feedback, where participants are given information via mail or the internet. Studies using non-continuous feedback generally show rather weak effects on energy consumption [7,9,10]. For continuous feedback, most studies find a significant reduction of energy use. For instance, in a recent Danish study using in-home displays, the average reduction was around 8%, compared to less than 1% in the control group during the five-month trial [11]. A literature review by Darby from 2006 describes electricity reductions between 5% and 15% for interested users of in-home displays showing both continuous and historic usage [12]. Other recent

studies [13–15] have provided additional knowledge about household characteristics and different types of feedback devices, and resulted in a number of recommendations. They include that individual and specific feedback should be provided to the households instead of generalized tips and information applicable to all households [12], the information visualised should be simple and easily accessible; simple diagrams and pregnant colour symbols are more important than the design concept itself; the distribution of consumption on each electrical appliance is important; and the information visualised on a display may be misleading if the user cannot distinguish between kilowatts and kilowatt-hours [16].

Feedback on electricity consumption in households might contribute to more sustainability in daily household life, yet according to [17] there is a need to know more about people's actual use of electricity and activity patterns in their everyday lives, especially if we are to develop sustainable guidelines and tools for these households. People's motivation to reduce their electricity consumption is also a vital factor to consider if display feedback to households is to be established [18]. The provision of improved and clear information about consumption data in general, and detailed information concerning the rent paid by tenants, are important initiatives that can complement technical interventions in buildings [19,20].

In order to develop new and more effective ways of designing feedback information, it is important to understand people's motives. Psychological motives are rarely investigated in connection with behavioural change and energy conservation [7]. Most studies in the area report on the effectiveness of different experimental interventions without asking *why* people react to them or not. However, there are some valuable exceptions in terms of studies that use a combination of methods, including focus groups and interviews [11,21,22]. These studies show that positive environmental attitudes, as well as an interest in and understanding of the IHDs and the information they provide, appear to be important factors in motivating the households to use the IHDs to engage in electricity-saving behaviour. The aim of the present research is to further investigate this picture and to explore additional motives and perceived barriers.

Two field experiments were carried out to study (a) the effects on energy savings of continuous visual feedback via in-home displays, and (b) the motives for responding or not. Two different types of housing were chosen. Study 1, a questionnaire survey, focuses on households in single-family and semi-detached houses, while study 2, an interview study, focuses on households in rented apartment blocks.

In both studies, the same type of in-home display (IHDs) was installed. The display provided the household with information on current electricity consumption, historical consumption (Day, Month, Year), as well as estimates of costs and CO₂ emissions from electricity consumption. In-depth information about the in-home display is presented in [Appendix A](#). In order to understand the motives, potential and barriers of continuous feedback in relation to supporting electricity conservation in households, the participants in study 2 were interviewed.

2. Study 1

2.1. Method

2.1.1. Sample and procedures

The study was carried out in cooperation with two Swedish power companies (Alingsås Energi and Eon) and a Swedish construction company (NCC). Separate or semi-detached houses in two municipalities outside Gothenburg (Lindome and Alingsås) were chosen for the study. 100 households were selected randomly

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