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Energy consumption feedback devices' impact evaluation on domestic energy use

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HIGHLIGHTS

- Effects of SMS, display, letters and TV feedback on consumption were evaluated.
- Consumers' opinion and feedback preferences were analyzed through questionnaires.
- Changes in consumption patterns explained by introduction of visualization method.
- In-home displays and TV caused the major reductions.
- Information relevant to the users should be included in feedback.

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ABSTRACT

Household energy accounts for one of the major contributors to the countries energy balances. It has been shown, that an effective way to achieve energy saving in that sector, is by providing consumers with information and feedback. This measure increases home inhabitants' awareness that leads to behavioral changes, and could help reduce energy consumption between 15% and 25% in some cases. Inhabitants' energy use awareness is also crucial for the success of demand response programs; one of the most important features of smart-grid adoption for the current and upcoming smart cities.

The effects of different feedback strategies and information devices in households located in different cities in Sweden have been evaluated in this paper, since the impact on users' behavior of this feedback information vary depending on the way it is provided.

Mobile text messages (SMSs) and digital displays placed in the building's common areas did not cause any noticeable behavioral changes, while the use of a TV channel and personal in-home displays were the most popular devices amongst households with high incomes.

This paper concluded that even though feedback helped reduce domestic energy consumption and induce behavioral changes, it only reaches the consumers interested in it. It is important therefore to provide customized information to the consumer and select precise feedback tools for specific household groups. Special attention should be paid to increasing the energy consumption awareness in households with low income levels.

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1. Introduction

Europe consumed 3170 TW h of electricity in 2008; 54% from burning fossil fuels, but what is more important, most of these fuels were imported (83.5% oil and 64.2% gas), increasing the supply dependency of the European Union [1]. Households alone, account for more than a quarter of the EU's total energy consumption. If all the office buildings' energy consumption is included, the building sector accounts for 40% of the total energy consumption in the Union [2].

In Sweden, the final use of electricity in 2009 reached 125 TW h of which the residential and services sector (formed by residential and commercial premises, holiday homes and land use) used 73 TW h, almost 60% of the total consumption. The total energy use in the sector was 149 TW h (residential buildings and commercial premises accounting for 87%) or 39% of Sweden's total final energy use [3].

Increasing domestic energy demand is transforming the households sector into one of the major contributors to the country's energy balances. Some forecasts show that in the near future,

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domestic energy consumption will exceed 40% of the total yearly consumption [4].

Large consumption differences found in buildings with similar characteristics (same number of occupants, same buildings' properties, similar income levels, etc.) confirm the strong influence that occupants' behavior has on the energy use [5].

Despite some prognostics showing stabilized levels of electricity consumption due to increased efficiency in domestic appliances, consumption is growing due to the intensive use of appliances together with a population on the rise [6].

In order to reduce users' impact on electricity demand, several strategies have been developed over time. Three of the main methods are mentioned by Wood and Newborough [7]: replacing the existing housing stock with low-energy buildings, promote use of high-efficiency domestic equipment and finally, promote energy-conscious behavior among the consumers. While the first two would be both time and money intensive, changes in behavioral patterns can save energy without additional investment in infrastructure with immediate results [8].

It is therefore essential to focus most of the efforts into increasing consumers' energy awareness and knowledge in order to achieve positive behavioral changes. Different research shows that users reduce their consumption due to energy-use information and feedback [9–11]. The effectiveness of the feedback would depend on the way it is delivered (web based, display, etc.) and the information it contains. It can be hard for some consumers to connect their behavior and everyday activities to the actual electricity consumption [12].

The main goal of this paper is to determine the effects of different visualization methods for energy consumption and the possible changes made in occupants energy–consumption awareness (through changes in the consumption patterns).

2. Background

Several researchers have tested different strategies to induce behavioral changes and to increase their energy consumption awareness on household users. Research has been directed towards evaluating those strategies and to establish the factors determining domestic energy consumption. In a recent study performed by the University of Gothenburg, 4000 Swedish households were selected by the Society, Opinion and Media Institute for studying patters of energy savings [13]. The most prominent socio-economic factors affecting energy consumption were found to be: age, housing type and household income. Also environment-related attitudes were found to have weaker effects on saving energy in owner-occupied detached houses. Homeowners seemed to react better to economic incentives. Households with higher incomes and living in non-detached houses (and apartments) were more sensitive to environmental attitudes. The study recommends that policy measures should be tailored to fit household preferences depending on income and housing forms.

Income is a factor which is also pointed out as one of the main factors affecting electricity consumption by other authors [5,14]. Moreover, consumers' income, dependent usually on their age also influences consumers' energy visualization preferences (the elderly consumers, with low income usually preferred letters, while those in their middle age usually with higher incomes preferred web sites) [15].

Ek and Söderholm, analyzed 564 questionnaires in Sweden, concluding that price incentives, information and environmental moral concerns are essential to promote less electricity use [16].

Sardianou analyzed the energy conservation in 500 Greek households using face-to-face interviews with one adult from each household [17]. The energy-saver consumer was characterized by having a high income, being the owner of the house and also being a member of an extended family core. On the other hand, the number of rooms, size of the dwelling, the sex, educational level and marital status could not be considered as predictors of energy conserving behavior.

Whether the consumers own the house or not was found by Palm to influence the largest part of their energy consumption [18].

Ndiaye and Gabriel, conducted a similar study in Canada including 221 phone surveys and 1-year electricity consumption data [19]. Amongst the 60 variables that were included in their principal component analysis, the number of occupants, the home ownership and the vocational period were selected as the main energy consumption predictors.

A number of researchers point out that behavior (as the action taken by the households in their use of energy at home) plays a major role in determining energy consumption [20–23]. It seems therefore logical to target different behavioral aspects when attempting to increase energy awareness and savings. This could be mainly achieved by providing feedback and information. These tools would also make the electricity more visible, especially important in countries like Sweden, where until recent years electricity was included in the rent. Different studies show that the way feedback is provided determines to a certain degree the saving achieved. Direct feedback (in-home displays) for instance, could save up to 15% electricity, while indirect feedback (bills) would only achieve reductions of 10% [10]. Consumption information provided through a web site reached saving by up to 18% however only within the group of households that had visited the web site frequently [15].

Consumers' preferences on the way of receiving feedback and information and their behavior and characteristics however have not been considered in most of the cases when utilities design their energy efficiency and awareness plans Table 1.

3. Methodology

The information gathered from the occupants was related to socio-demographic variables, lifestyles, feedback preferences and their thoughts on the provided energy consumption devices. Questionnaires were chosen to collect such information due to compatibility and comparability with previous research where the effects of a web based feedback were evaluated [24]. Four different parts could be distinguished in the questionnaires, some of them common to all households groups. At first, questions focused on information about the occupants (level of education, monthly income, how many people live in the apartment, how many weeks the occupants spent away from their home and age of the respondents

Table 1
Description of all household groups.

	Location	Households total/responded	Visualization device	Period of collected consumption data
Group I	Gothenburg	80/28	In-home display; SMS; letter	January 2011–May 2012
Group II	Malmö	28/10	Common display	June 2011–February 2012
Group III	Hägersten	81/44	In-home display	March 2012–May 2012
Group IV	Sollentuna	70/29	TV-channel	December 2011–June 2012

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