



Factors influencing residents' energy use—A study of energy-related behaviour in 57 Swedish homes



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ARTICLE INFO

Article history:

Received 10 July 2014

Received in revised form

30 September 2014

Accepted 4 November 2014

Available online 11 November 2014

Keywords:

Energy-related behaviour

Residents

Time use

Diary

Energy measurement

Cluster analysis

ABSTRACT

The aim of this work has been to study everyday energy-related behaviour in homes. All residents in 57 Swedish homes, living in three housing areas, have recorded time diaries over a period of four days, during the same time period in each area. The technical differences between the houses are limited, as the building designs within each housing area are the same. On an aggregated level, the diary data has been analysed with and without typical power data of appliances as well as in relation to measured total energy use, indoor temperature and water usage. Cluster analyses have been performed in order to find characteristics of groups of residents with regard to their energy-related behaviour. Some of the findings were that residents report long time use/operating time for activities related to electronic equipment (45% of total reported time). Residents which used energy to a greater extent than others were characterised by performing activities with long operating times, in combination with high, and fairly high, typical power ratings. The majority of residents showed many different energy-related behaviours, which indicates that a number of strategies to influence the behaviours – not just one – will be required.

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1. Introduction

On the global level, the residential sector dominates energy use in the building sector, with use having increased by 32% between 1990 and 2009 (measured in joules) [1]. The equivalent figure for OECD countries is 18%. This includes a rapid increase in electricity use in all regions. At the same time, world population is increasing, and the number of households is predicted globally to grow even more, as there is a trend of fewer persons per household. Larger floor area per household is another trend in the residential sector [1].

Improved energy efficiency is one of the most important ways of reducing the negative effects of these trends, and has been so over the past decades. The energy-related behaviour of households plays an important role in realising energy-efficient measures in an effective way. This behaviour can be related to implementation and acceptance of new technology, maintenance of equipment and the use of energy. To a great extent, energy-related behaviour influences the gap between potential and actual energy efficiency levels [2].

Households' energy-related behaviour can be categorised as illustrated in Fig. 1, with different kinds of behaviour sorted

by frequency and cost. It can be seen that some improvement actions occur relatively infrequently, such as replacing traditional light bulbs with low-energy bulbs or installing new seals around windows and doors. Such measures are relatively inexpensive, but their effect can be significant. Other decisions relate to more substantial improvements, usually with higher costs, and need more consideration. Examples include the purchase of refrigerators and freezers, televisions, computers or new heating systems. These purchases are usually made when the old equipment is worn out and discarded. Then there are habits and behaviours that occur on a daily basis and that often become routine. Small changes in daily activities can eventually make a big difference in energy use, often with no cost associated with these changes. Examples of this type include how laundry is dried or for how long people take in a shower. This article is mainly concentrated on these daily activities. Strategies to influence energy-related behaviour should be designed with these categories in mind [2,3].

It is generally difficult to put a specific figure on the potential savings from changed energy-related behaviour. A general estimate, often seen, is approximately 20%—however, the reference for this figure is not completely clear. In an American study, a number of common energy-saving actions related to behaviour in the 'No/low cost' category amounted to potential savings of approximately 12% [4]. In another American study, the savings are estimated to similar figures, but included transportation behaviour as well [3]. Older studies, e.g. Palmborg [5], estimate the potential

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| | Infrequent | Frequent |
|-------------------------|--|--|
| No/low cost | Stocktaking behaviour Energy-efficient lighting (e.g. LED) Temperature set backs Draught proofing | Habitual behaviour and lifestyles Turn off computer and other devices Air-dry laundry Take short showers Use energy-efficient washing programs |
| Higher cost /investment | Consumer behaviour Energy-efficient white goods/appliances Energy-efficient windows Additional insulation Heat pumps | |

Fig. 1. Households' energy-related behaviour, focused on some examples in single-family houses [3].

savings of total energy use to be about 10%. Various studies also show great variations between similar houses that cannot be explained by technical differences alone; energy behaviour is thought to contribute to the substantial differences [6–15].

This paper is part of the overall “Energy use in single-family houses—The significance of residents' behaviour” project, where 57 households participated in a diary study of everyday behaviour. The diaries recorded the time used for everyday activities in the households. In parallel with the diary keeping, energy use in the houses was measured. The overall goal is to use the knowledge derived to contribute, long-term, to the reduction of energy use in the residential sector. This paper focuses on the results from the diary study, and relates these data to measurements of total energy use in the participating households. The objective is to find out what kinds of activities characterise households' energy use. In [15] details of the measurements are presented including households' energy use, indoor temperature and water use as well as load profiles.

Time diaries have been used and analysed in other studies, particularly in projects related to people's everyday behaviour conducted by Ellegård and colleagues at Linköping University in Sweden [16–19]. However, few studies have linked energy-related behaviour with direct measurements of energy use. There are examples of studies that have combined measurements and diaries with a focus on a few activities, such as dishwashing habits [20] or lighting patterns and presence in offices [21]. There are also examples of smaller studies where hot water usage as well as electricity usage in households have been studied together with diaries in order to identify usage and load patterns visually [22,23]. Other studies use national time-use data for modelling household profiles or to develop and validate models, e.g. [24–31]. There are also studies that relate time use data or diary notes to energy issues [18,32–34] and water consumption [35–37]. However, there is a lack of larger studies which connects actual behaviour with energy measurements. There are many questions to be answered regarding the residents and their activity patterns associated with energy use. Trying to describe and explain the residents' influence is important for energy planning and in order further to study different types of behaviour profiles. The project mainly complements previous studies, in which only a few households have participated, and focuses on differences between households where the construction and building services systems of the houses are similar.

1.1. Research objectives

The objective of this paper is to find characteristics of energy use in houses. How and in what way the energy use differs between different households in similar houses is specifically highlighted. The paper is focused on explanatory factors related to family composition, behaviour and other household-related factors.

Table 1
Categories of participating households.

| Household types | Housing area | | | Sum |
|---|--------------|----------------|----|-----|
| | A | B | C | |
| I Single persons, 26–64 years | 1 | 0 | 0 | 1 |
| II Single persons, 65 years and above | 0 | 0 | 0 | 0 |
| III Couples without children, 26–64 years | 7 | 3 | 4 | 14 |
| IV Couples without children, 65 years and above | 0 | 5 ^a | 0 | 5 |
| V Families | 14 | 11 | 12 | 37 |
| Total number of households | 22 | 19 | 16 | 57 |
| Total number of persons | 66 | 52 | 53 | 171 |

^a One couple has been categorised as household type IV, although they are not 65, because they are close to retirement age and because one person in the household is retired (disability pension) and the other person was unemployed at the time of measurement.

1.1.1. Research questions

Questions that will be answered in this paper are:

1. What everyday energy-related behaviour is performed in homes? And for how long?
2. Can common characteristics be identified between different types of consumers?

1.2. Limitations

The main limitations of the study are:

- Only houses built on housing areas with several similar houses are included.
- Only total energy used is measured.
- The measurements are made during three different periods for the three housing areas.

2. Material and methods

2.1. Houses and residents

The three groups of houses included in the project were considered to represent “common houses”, all built in the 1980s. Electrically-heated detached houses were chosen, so that their energy use would be easy to measure and could be associated with each individual home. Within each housing area, the houses were nominally built in the same way—thus the households' energy use could be compared without having to take the buildings' design into account. The houses are further described in [15].

57 households living in the three housing areas participated in the study. In total, the households comprised 171 family members, whereof 134 were 12 years old or above, and were asked to write individual diaries. In the end, 141 persons wrote diaries for four successive days (a number of children younger than 12 wanted to participate and two couples wrote only one diary instead of two individual diaries), which means 564 diary sheets were completed (four days and nights).

Table 1 shows the different types and numbers of households based on family composition. The categorisation is based on the report “End-use metering campaign in 400 households in Sweden—assessment of the potential electricity savings” [38]. It should be clarified that the category “Families” includes couples with one or more children as well as a single parent with one or more children. In a few cases, households do not belong to one of the stated categories.

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