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Energy efficiency in every-day household life
Three scenarios

Abstract
Households will play an important role in saving electricity in the future. Behavioural aspects in using white goods and other electric appliances are important as are the reasons for buying new white goods and a number of other appliances for cooking and washing. In a Swedish study three important aspects of energy use in households , *Washing/drying Laundry*, *Cooking and Eating*, and *Information and Entertainment* were analysed. These areas include activities performed almost daily in households. In the study , the number, make and model of all electric appliances were recorded, as was the way they were used and by which family members. Some white goods for washing and cooking were very old, but were candidates for replacement only in young households. Electricity use, behaviour, buying and replacement and number of machines differed between young and old households, with number of persons in the household and between families living in apartments and those living in houses.

Scenarios on the electricity savings potential of combining behaviour and replacement strategy for white goods were calculated for the three areas of electricity use, and discussed in relation to the need for policy instruments to bring about changes in behaviour or in replacement strategy for old appliances.

Key words: behaviour, electricity use, households, scenarios

Introduction

Electricity is involved in almost every type of consumer behaviour electricity is involved either in producing goods or in using appliances in everyday life. About 36 percent of the total energy use in Sweden derives from the housing sector (Energimyndigheten, 2007; Lindén, 2008a). However, in the housing sector energy use for heating and hot water has decreased during the past decade due to more efficient technology and to a large number of households having added different types of heat pumps to their electric heating system. In households electricity consumption for heating and hot water is as high as 60 percent. However, electricity consumption for other domestic uses has increased since the 1970s and now makes up 40 percent (Lindén, 2008a). The increasing number of households in Sweden is one factor behind that trend. Other factors are increasing numbers of electric appliances in households and behavioural changes in using appliances, especially among young households.

Electricity as a product

Electricity as a consumer product is necessary to fulfil a number of important functions in everyday life, for example chilling and freezing food products, cooking, laundry, lighting the home, and using computers and TV sets. Electricity differs from other consumer goods by not being visible to consumer

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in the same way as a TV set, fridge or other household appliance (Lindén, 2008a). Electricity must be purchased to make appliances provide the functions required, but consumers generally have no knowledge of how much electricity is needed and thus not even of the cost. Afterwards, when the service provided is consumed, the consumer pays the electricity bill. On average a household living in a private house uses about 6 200 kWh per year at a cost of about SEK 9 000 (EUR 818).[2] Families living in houses very often comprise more than two members and houses normally have more rooms than apartments. Households in apartments use about 2 800 kWh per year at a cost of about SEK 4 000 (EUR 365). These households normally contain fewer members on average, live in one- to three-room flats and comprise very young or old people. Thus electricity costs consume a substantial share of household income.

The cost of electricity has always been much lower in Sweden than in other European countries and Swedish consumers were not accustomed to considering their electricity use until recently, when prices began to steadily increase and are now approaching European levels. The need to be aware of electricity use is thus a quite new phenomenon for Swedes.

Households as electricity consumers

There are a number of functional areas where electricity is used to make everyday life comfortable and pleasant, e.g. food cooking/storage, dishwashing, washing/drying laundry, lighting and information/entertainment appliances (Carlsson-Kanyama A, Lindén A-L & B Eriksson. 2003a-b; Lindén, 2008a). In a national perspective these functional areas consume about 40, 20, 20 and 20 percent of household electricity, respectively (Bennich, 2007; Lindén, 2008a). There are differences in electricity use between households living in houses and those in apartments. A study in an urban area of Sweden showed that households living in apartments and houses use almost the same proportions of electricity in functional areas with one exception, lighting has a higher proportion electricity used in houses, due to their larger size and generally larger number of family members (www.vaxjo.se/vaxjo_templates/Page.aspx?id=6255). However, it should be borne in mind that the total amount of electricity used by households living in apartments is less than half that used by households living in private houses.

There are also differences in electricity use between households in relation to income and age. The older generation are more likely to adopt energy-saving strategies, e.g. always turning lights off and not leaving other appliances on standby. Behaviours like this stem from patterns learned during less affluent periods in life (Mannheim, 1952; Gram-Hansen, 2003; Lindén, 1994, 1996, 2008a). On the other, hand young people are more used to modern technology and to low-cost electricity, so using the standby mode or having computers or TVs running while doing something else does not bother them from an economic aspect (Lindén, 2008a). Behavioural differences in using entertainment appliances and computers are a very important factor behind the higher amount of electricity use among young people (Carlsson-Kanyama A, et al., 2003a-b). Another factor is the number and age of appliances in the household.

Attitudes, behaviour and technology

A common belief is that knowledge is the most important factor in developing attitudes. Education is one way to improve knowledge, but another way is to use information strategies addressing defined problems in order to influence attitudes and behaviour. It has been claimed that attitudes must be developed before behaviour can be changed (Ajzen & Fishbein, 1980). Thus a positive attitude to using electricity in an energy-saving way ought to promote several aspects of energy efficiency in behaviour. However, a change in habits often occurs the other way around in that something new is tested more or less by chance and found to be covennient or good enough to promote a change in behaviour and attitudes (Biel, 2003; Warde, 2005).

Nine out of ten Swedes have been concerned about environmental problems for several decades (Bennulf & Gilljam, 1991; Lindén, 2004; NV, 2007). Greenhouse gases are top of that list, withglobal warning second and energy production and energy use third. Thus awareness is high and knowledge about the climate consequences is proving frightening for a large number of Swedes. Knowledge about what can be done by individuals in everyday life has gained high awareness in a few aspects.

[2] Calculated on a cost of SEK 1,42 per kWh, including taxes and transmission costs.

However, it is difficult to relate global environmental problems to behavioural aspects when it comes to using products without a visual reminder. In a survey focusing on energy use respondents were asked to rank a number of behaviours in terms of their benefits for the environment (Carlsson-Kanyama et al., 2003a). The results showed that waste recycling has become more or less a symbol of high environmental concern (Table 1). Energy-saving behaviours also have a high ranking, e.g. saving energy in general and turning off lights in empty rooms. Campaigns recommending this type of energy-saving behaviour have been introduced on several occasions since the oil crisis in the 1970s and most people know exactly which attitudes are correct and sometimes what to do, but actually doing it is another question. In spite of favourable attitudes to energy-efficient behaviour, there are obstacles to overcome in adopting such behaviour (Carlsson-Kanyama et al., 2003a-b). Other aspects of energy use may be ranked higher, e.g. lit rooms may look cosier although they are empty. Positive attitudes are not always followed by a consistent behaviour and therefore attitudes are a bad predictor of behavioural outcome.

Table 1. Ranking of important factors in terms of their benefits for the environment. Scale 1-5, where 5 indicates very important and 1 not important.

Behaviour	Mean	No answer, %
Waste recycling	4,0	1,5
Saving energy	4,0	2,5
Decrease car travel	3,8	2,5
Turning off lighting in empty rooms	3,6	2,5
Buying eco-labelled products	3,4	2,7
Decreasing meat consumption	2,1	6,4

(Carlsson-Kanyama A, Lindén A-L & B Eriksson. 2003a-b)

The technological design of appliances is sometimes a determining factor for consumer behaviour. One study found that heat regulators on radiators were used so seldom that they were impossible to turn and thus it was easier to open the window and let the heat out. Electronic appliances have standby buttons to make turning on and off easy for the user. Many appliances do not have a turn-off button at all, so it is impossible for users to turn off these machines completely without unplugging them. All appliances should be easy to use and turn off or wall sockets should have an in/off switch making it possible for those who want to save electricity to do so (Karlsson & Widén, 2008). All households have a great number of electrical appliances and decisions to buy new or replace old appliances are taken by the members of the household. Buying new appliances includes buying more electricity to serve the function intended. Although many appliances nowadays have an energy rating or at least a table of technological specifications, the determining factor for the buying decision is very often the function and design wanted. Energy efficiency plays a minor role or is not considered at all.

Although individuals have a high environmental awareness when it comes to energy use, there is room for improvement when it comes to energy efficiency. The non-visual product electricity has to be made visible and become an important determining factor in decisions on buying appliances and introducing energy-efficiency aspects of behaviour. Behavioural aspects of reducing energy use have been neglected to date, while technological aspects have been prioritised (Brown, 2008).

The research problem

The objective of this study was to analyse the electricity-saving potential of changing behaviour and/or replacing ageing electric appliances in three functional areas in households, *Washing/drying Laundry, Cooking and Eating,* and *Information and Entertainment.* Scenarios were calculated to exemplify the potential energy-saving capacity of combining new technology and behavioural changes (Lindén, 2008a). The number of appliances providing functions and convenience within the three study areas are very different, as are decisions about what is needed and how it should be used.

Washing/drying Laundry: Washing machines, tumble-dryers and irons rely on established, well-known and nowadays very energy-efficient. At the same time textiles have been improved so that they can be

washed at lower temperatures and do not require ironing. Mature technology and improvements in textiles have brought new ways of washing and drying laundry in the home.

Cooking and Eating: Refrigerators, freezers, cookers, microwave ovens, food processors, kettles, dishwashers and a number of other machines providing convenience in storing and cooking food, as well as cleaning chinaware, represent a functional area where new appliances are constantly being introduced, especially devices such as rice steamers, egg boilers, hot dog heaters and all sorts of small electric appliances. White products such as cookers and freezers represent mature and energy-efficient technology, while most small appliances are fashion-related but are regarded by many consumers as more or less essential tools in a modern kitchen. The number of appliances is normally high. The frequency and behaviour in using them differs between households of different ages and income groups.

Information and Entertainment: Computers, radios, TV sets, CD players, mobile phones, wireless phones and chargers are appliances belonging to the functional area of information and entertainment. The speed of development for new appliances and for new services in existing home electronic appliances is extremely fast. Having up-to-date technology is very attractive for young households, as is owning and being able to use the machines whenever time becomes available. In a substantial number of households every member has a computer, a TV set, a MP3 player etc., which has resulted in changes in behaviour and in the way home electronics are used. Consequently, electricity use for information and entertainment accounts for a growing share in households, not least due to the frequent use of standby buttons on these kinds of appliances.

Methods and empirical material

The calculations in scenarios and the analyses were based on a range of empirical material:

1) Attitudes to environmental problems and energy-saving behaviour. Data on number of appliances in functional areas, income groups and generations living in private houses and apartment buildings were taken from a survey of 600 households in a Swedish city. (Carlsson-Kanyama et al., 2003 a-b).
2) Electricity use in for different purposes in households: Data were taken from a study on 400 dwellings administered by the Swedish Energy Agency (Bennich, 2007).
3) Electricity use in households: National data were obtained from the National Census Bureau and the Swedish Energy Agency (www.scb.se/databases/ , www.enegimyndigheten.se)
4) Generations, age groups, size of households, income: Data for households living in different types of buildings and forms of tenure on a national scale have recently been calculated and were partly used in this study (Lindén, 2007a).

Results and discussion

Over ten years the proportion of electricity used for washing/drying laundry in households has decreased tremendously (Lindén, 2008a). Electricity use for cooking and eating has also decreased, while the share of electricity used by households for information and entertainment purposes has increased. Such trends reflect the rapid rate of innovation in home electronics. However, new technology is not the only factor behind the increase in overall electricity use in households. Another important factor is the impact of changing behaviour, and the frequency of replacing appliances.

The number of electric appliances in households has increased enormously over a period of about sixty years (Strandbakken, 2007, Lindén, 2008b) although the actual numbers differ between functional areas. Machinery for washing and drying of laundry has not increased at all during this long period (Table 2). However new laundry appliances are much more energy-efficient in use than older models and a lower washing temperature is sufficient for modern textiles. Laundry washing/drying appliances represent mature technology, which means that any energy savings are dependent on replacing old machines and on practising energy-efficient behaviour in using them.

The share of electricity used for cooking and dishwashing has recently declined, in spite of technological innovations leading to an increased number of new appliances in this area. However, most of these are not in daily use. The most frequently used machines, e.g. cookers, freezers, refrigerators and dishwashers, are continually becoming more energy-efficient to use. However, there

are still a large number of old appliances in use. Another relevant trend in Sweden and other European countries is for home cooking during weekdays to be replaced by dishes that can be made easily and quickly (Carlsson-Kanyama et al.,; EU, 2004; Lindén, 2008a). However, the average number of food-related appliances has increased to more than ten during the 60-year period (Table 3). The number of machines, as well as their mean age and use differs between generational groups.

Table 2. Average number of appliances in three functional areas owned by households, 1950 and 2000. (mean values for year)

Functional area	1950	2000
Washing/drying Laundry	1	3,0
Cooking and Eating	2	10,3
Information and Entertainment	2	18,0

(Lindén, 2008b)

In the third functional area, information and entertainment, the average number of appliances has grown very rapidly to 18 during two decades since their inception (Table 3). These appliances are often replaced very frequently due to innovations in all sorts of home electronics and are very common in young households, where family members often have their own appliances. Several appliances are often used at the same time or are left in standby mode (Ellegård, 2008; Karlsson & Widén, 2008). Not only the technology but also the behaviour in using them has changed in many households.

Saving electricity in households – three scenarios

Scenario 1: Washing/drying Laundry
Electricity for washing and drying laundry currently comprises about 20 percent of electricity used in households (Lindén, 2008a). At the same time washing and drying of laundry has undergone a revolution over a period of about sixty years. Every household living in a private houses has its own washing machine and tumble-dryer, as a growing number of households living in apartments. Other households living in apartment buildings have access to a laundry room in their building. In addition every household has a larger amount of laundry nowadays than previously so there has been no decrease in the time used for washing and drying, although the task has become less onerous (Lindén, 1994). The machines used are generally quite old, seven years on average. Households living in private houses, particularly households with older people, have machines that are more than ten years old on average (Lindén, 2008a). Landlords of apartment, washing machines, tumble-dryers and other equipment for drying laundry are usually new in apartment buildings. The potential for electricity savings is definitely high if most old washing machines and tumble-dryers are replaced by modern appliances in households living in private houses.

Table 3. Scenario 1 - *Washing/drying Laundry.* Potential electricity savings for the period 2008-2012.

Households living in private houses	Number[3] of households	kWh/year today[4]	kWh/year modern machines[5]	Electricity savings
Machine change				
in 5 years	1 100 000	1 100 000 000	677 600 000	**422 400 MWh**
in 1 year	220 000	220 000 000	135 520 000	84 480 MWh

(Lindén, 2008)

[3] Number of households living in private houses 2 200 000:2 =1 100 000 replace their device in 5 years, 220 000 households per year.
[4] Energy use for old machines in houses is calculated to be 1 000 kWh (STEM, 2007).
[5] 384 kWh in energy use for modern machines (STEM, 2008).

In almost all Swedish households, environmental awareness scores high and is matched by energy-efficient behaviours, e.g. only washing full machine loads and not using the tumble-dryer unnecessarily (Carlsson-Kanyama et al., 2003a). Thus the potential for energy savings in this functional area by changing behaviour in washing and drying laundry is minor.

If one-fifth of households in private houses that own machines older than seven years on average, replaced their machines within a five-year period the potential energy saving would be 422 400 MWh Table 3). Of course there is also minor potential for changes in behaviour among small households if they filled machines to a greater extent than today, which has been calculated to generate electricity savings of about 42 000 MWh within the same five-year period (Lindén, 2008a).

Scenario 2: Cooking and Eating
Electricity use for cooking and eating has a share of about 20 percent. There are differences between generations. In households with older members more time is used for cooking than among young households (Carlsson-Kanyama & Lindén, 2001; Lindén, 2008a). On the other hand the dishwashers, cookers, refrigerators and freezers are more modern and more energy-efficient in young households than in old. The number of appliances used is greater in young households than in old. For example electric kettles, which are very energy-efficient, are more often used by young people. However, differences in time for cooking and the number of old and new machines must be studied in more detail before they can be included in a scenario.

In calculating scenarios it is more important to focus on the energy-efficiency of machines used daily in young households compared with old, e.g. cookers, refrigerators, freezers and dishwashers. on average the mean age of dishwashers, cookers and refrigerators is seven years, and the mean age of a freezers is nine years (Lindén, 2008a). According to STEM (2001; 2008), replacing these machines with appliances of maximum energy-efficiency would save 995 kWh of electricity per household every year. These figures were used in scenario 2 (Table 4).

Table 4. Scenario 2 - *Cooking and Eating.* Potential electricity savings for the period 2008-2012.

Households living in houses	Number of households [6]	kWh/year 6,5 year old appliances[7]	kWh/year new appliances	Electricity savings
for 5 years	1 100 000	2 265 000 000	1 314 500 000	**1 050 500 MWh**
for year	220 000	473 000 000	262 900 000	210 100 MWh

(Lindén, 2008)

If households with dishwashers, cookers, refrigerators and freezers older than the mean age replaced these appliances within a five-year period the calculated energy savings would be about 1 050 500 MWh (Table 4).

Scenario 3: Information and Entertainment
The rate of technological innovation in appliances for information and entertainment is very rapid. Machines introduced just 25 years ago, e.g. the video player, were old-fashioned ten years ago and cannot be bough tany longer (Bladh, 2005). The functions they performed, e.g. recording TV programmes, are now being provided by new machines, DVD-players, with extended services and more modern technology. In a field with a high rate of innovation there are few old machines in use that can be compared with modern appliances in terms of electricity use. Thus it is more important to analyse the ways in which new technology is leading to changes in behaviour concerning information or entertainment equipment in families (Lindén, 2008a). As has already been stated the expanded ownership of all sorts of home electronics has reduced the time spent together in families. When several family members have their own computer, they can use their machines at the same time, a process known as parallel use (Ellegård, 2008). No-one needs to wait for their turn for the only

[6] Number of households living in private houses 2 200 000/2 = 1 100 000 households replacing their machines within a five year period.
[7] Old machines consume 2 150 kWh/year, household. Modern machines of best energy efficiency consume 1 195 kWh/year, household. The amount of energy saving is 955 kWh/year, household (STEM, 2008).

computer in the family any more. Parallel use of appliances such as computers, TV sets, radios, CD players, MP3-players, etc. is a very dominant pattern in families owning several sets of machines. However, as these use patterns are still developing rapidly, it is not possible to find robust observations on this phenomenon in a time perspective.

Another question is what behaviour in electricity use is lost when new machines are introduced. Besides using more electricity in parallel use patterns, the behaviour of turning off machines fully has been replaced in that modern appliances, e.g. TV sets, computers, players, have standby buttons regulated by remote controls. This innovation makes it more convenient for uses to turn on equipment and change channels. On the other hand it has been calculated that about 10 percent of electricity use in households comes from machines and chargers left in standby mode (Lindén, 2008a). The electricity use in standby mode is included in scenario 3 (Table 5).

Table 5. Scenario 3 - *Information and Entertainment*. Potential electricity savings by avoiding use of the standby function for the period 2008-2012.

Number of households 50 %	Electricity use TWh/year 50 %	Standby electric use TWh/year 10 %	Standby function TWh/year 5 %	50% electricity saving TWh/year	TWh/5 years
2 300 000	40 TWh	4.0 TWh	2.0 TWh	1.0 TWh	**5.0 TWh**

(Lindén, 2008a)

There are differences between households in number of appliances owned and also in the frequency of using standby mode. Households of older people have fewer appliances for information and entertainment and they are accustomed to turning off equipment fully and not using standby mode. In contrast young households and households with children have a great number of machines and more frequently use the standby function as it is convenient. Knowing the number, size and age of households, about 50 percent of Swedish households could be expected to make changes in their use of standby functions on information and entertainment equipment (Lindén, 2008a). Some devices are constantly left on standby, e.g. mobile phone chargers, built-in clocks, computers, with a calculated electricity use of 10 percent. In scenario 3, it was assumed that half this electricity use could be avoided by turning off machines fully or unplugging chargers. By changing behaviour in these respects, about 5 TWh electricity could be saved in households.

Conclusions

This study examined whether it is possible to achieve a substantial amount of electricity savings by changing behaviour in using appliances and/or replacing old machines within the functional areas *Washing/drying Laundry; Cooking and Eating* and *Information and Entertainment.* The three scenarios calculated using available data showed that in a five-year period a total of 7.7 TWh electricity could be saved (Table 6).

Table 6. Electricity savings from the three scenarios of electricity use in households over a one-year and five-year period.

Functional area	Electricity savings, TWh for 1 year	5 years
Washing/drying Laundry	0.1	0.4
Cooking and Eating (private houses only)	0.2	2.2
Information and Entertainment (only standby)	1.0	5.0
Total electricity saving, TWh	1.3	7.7

The assumptions behind changed behaviour and replacement of old machinery related to number and age of appliances and their use. If more aspects had been included in the scenarios, the electricity savings would probably have been higher. However, in order to perform such an analysis, there is a need for research and empirical data concerning use patterns and appliances in different kinds of households.

The question is how to implement new behaviour and decision-making in replacing old technology? The first answer is to make electricity a visible product, e.g. by labelling products not only with their energy-efficiency, but also with electricity use over time, e.g. the electricity needed for ten hours of computer use. Information in relation to behaviour and use patterns could be a complement to energy labelling, which is more abstract information for the consumer (Lindén, 2007b). Economic measures, e.g. subsidising new household appliances and removing and disposing of old appliances, is another example of an efficient measure (Lindén, 2007). Knowing that the old machine will be removed and that there is a reduction in price of a new appliance is normally very attractive to customers, causing them to replace machines earlier or to buy more energy-efficient machines.

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