Energy Services in Sweden - Customer Relations towards Increased Sustainability

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Doctoral Thesis

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The end users' poem

Energy, energy, energy
The hub of a modern society
Invisible, inbuilt, but there
Lights are on everywhere

Energy, energy, energy
Convenience yet efficiency
I don't want to see where it's made
Just you don't put me in shade

Energy, energy, energy
Service or a commodity?
Am I a customer, household or mode?
- Or do you simply see me as load?

Energy, energy, energy
Beware, a polluting utility!
I want the world to be clean
Please colour the electrons green

Abstract

Energy use and supply are evident issues to consider for a sustainable development, where the economic, social and environmental aspects are all important. In large grid-bound systems like electricity and district heating systems, the supply of energy is usually a rather invisible activity and the contacts between household customers and utilities are sometimes only represented through the energy bill. There are, however, many reasons to enhance this interaction between household customers and their utilities. In this thesis, three particular fields are emphasized where these interactions comes into focus: *Electricity peak load problems and load management in households*; *Energy monitoring and feedback*, and; *The selling of district heating to households in detached house areas.* Improved customer relations in these areas can both increase the energy utilities abilities to compete on the markets *and* to contribute to an increased sustainable development within the energy sector.

In electricity systems, there is a need of constant balancing the use and supply due to the fact that electricity cannot be stored per se. In the Swedish electricity system, peak load problems are highly weather dependent due to the large share of electric space heating in detached housing areas. The traditional ways to handle these problems have been to find solutions on the supply-side: to build new power plants and to reinforce the electricity grid. For economic and environmental reasons, solutions can also be found on the demand-side, trying to influence the users' load patterns. This thesis discusses the issue of direct and indirect load management through technical load control of households' electric heating systems and electric water heaters, and through indirect load management with different pricing of electricity. Several methods are used to investigate the technical, economic, environmental and social aspects of direct load management, i.e. energy diaries, frequent electricity metering on partial loads and a load control experiment at ten households in detached houses. Tariffs are analysed and discussed with customers and through a techno-economic analysis of a particular tariff with a peak load component used by the Swedish utility Sollentuna Energi.

The new Swedish law about monthly accurate billing of electricity for household customers has influenced the electricity network owners to install new automatic meter reading (AMR) systems. The possibilities of hourly metering can give raise to a new set of data about household electricity use. Analysis of this data can provide detailed characteristics of load demand and consumption patterns and serve as a basis for customer segmentation. This information can be useful when developing new energy services, new pricing of electricity, new load management strategies and demand response programs. In this thesis, customer preferences towards feedback on electricity use and different types of billing are investigated in a questionnaire study. The result from this study can contribute to important knowledge of customers' need and awareness of different kinds of feedback.

Conversion of electric heating systems and electric water heaters to district heating can contribute to solve some of the peak load problems in the Swedish electricity system. Conversion to district heating also have other advantages, for example, it can lead to lower emissions in the energy system or it can constitute a new heat demand needed for new introduction of Combined Heat and Power (CHP) plants. Effective market strategies are important in order to achieve a high connection rate of household customers to the district-heating grid. The knowledge of customer preferences, attitudes and decision-making processes play an important role when developing such strategies. Two studies in this thesis investigate these issues and the Swedish district heating companies' sales strategies in detached housing areas: one questionnaire study sent to the district heating companies and one interview study carried out with households offered to convert their direct resistive electric heating systems to district heating. The results from these studies can contribute to the development of more effective marketing strategies for district heating companies.

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1 Introduction

Energy production and distribution are important parts of a sustainable development. The concept has been widely used ever since the report *Our Common Future* in 1987, usually referred to as the Brundtland Report, and the definition from this report is probably the most frequently used (WCED, 1987):

> "Sustainable development is development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs."

Many definitions have been invented over the years, but most of them can be criticized for not being operational, which makes the concept rather vague. Sustainable development covers three general policy areas:

- Economic sustainability,
- Environmental sustainability,
- Social sustainability,

whereas green development mainly considers environmental sustainability.

The intention of using the construct of sustainable development here is not to come up with a new, revealing definition, but rather to emphasize the importance of the attempts made when trying to cover economic, environmental and social sustainability in the planning for future developments in the society.

Sustainability with respect to energy could be interpreted to stand for (Roels, 2005):

- Access to energy services for all people
- Availability and reliability of energy services
- Acceptability by society based on safe and responsible use of energy resources by industry

This view, Roels wrote, is visionary and requires far reaching steps in order to be fulfilled:

> "Total **accessibility** would imply that modern energy has to be brought to the 2 billion people in poorer countries that currently lack access. Furthermore, energy would have to be available at affordable prices in all regions in the world. **Availability** incorporates high quality and reliability of energy supplies. This implies the near elimination of supply interruptions such as blackouts and brownouts of power systems. Certainly, where energy supply systems are already well established, securing availability is an ongoing challenge. Finally, **acceptability** presumes that environmental and social targets and public attitudes are consistently addressed in all regions of the world in the coming years. Given the very extensive environmental debate in Western Europe and North America, **acceptability** comes with some major issues especially in some parts of the developed world." (Roels, 2005)

This interesting view focusing on accessibility and system reliability is also pinpointing the question of global equity. Energy systems have to grow, but at the same time, economic, environmental and social concern must be taken. The concern for populations in many developing countries is not to conserve energy for environmental reasons, but to get access to energy at all. This is a very different situation from that in industrial countries, where infrastructures and large technical systems for energy supply have been built into the society for many years and today, the citizen consumers are using the energy without much consideration of the expensive embedded systems providing the services.

Renewable energy and energy efficiency sometimes are said to be the "twin pillars" of sustainable energy policy. This is the view of a report from the American Council for an Energy Efficient Economy in 2007, where the authors stress the statement that both energy efficiency and renewable energy must be developed aggressively in order to stabilize and reduce carbon dioxide emissions within our lifetime. Energy efficiency is important because if energy demand is growing too fast, renewable energy technologies cannot catch up with it and will not substantially reduce the usage of fossil fuel. According to this report, some synergy effects can also be found between energy efficiency and renewable energy when it comes to timing, economic aspects, geographic aspects, power system synergies and other issues (ACEEE, 2007).

An explanation of the constructs "energy efficiency" and "renewable energy" may be appropriate here. *Energy efficiency*, simply put, means using less energy to provide the same energy service. This can be done by technical improvements or innovations in energy production, transmission, distribution and usage. In physics and engineering, the energy efficiency of a process is denoted as η, and defined as *output* – the amount of mechanical work or energy released by the process – divided by *input* – the quantity of work or energy used to run the process.

Renewable energy, on the other hand, refers to energy that is produced – in the economic sense[1] – from natural resources that are replenished at a fast pace. These natural resources are sun, wind, rain, tides and geothermal heat, which are utilized through different technologies

[1] In a physical sense energy is inconsumeable, but from an economic view point natural resources can be refined and from this energy can be produced, distributed and sold to customers. The customers consume it in the sense that they cannot retrieve it after usage.

like solar power, wind power, hydro power, biomass and biofuels used for making electricity or heat, or as fuels for transportation. Renewable energy systems are very important as a research area today, and investments in this field will become more and more beneficial the higher the prices of fossil energy become.

If all our energy came from renewables, one would think that energy use wouldn't be coupled with environmental problems anymore. But this is not entirely true. The sources that today are considered renewable still have some environmental implications. Hydropower, for example, means exploitation of rivers and waters, thus putting up dams in large water reservoirs. The amount of water increases in the dam but decreases in the river below and natural waterfalls are transformed. This affects the ecosystems of the river and the spawn of fishes like salmon and eel. Biomass is considered CO_2 neutral in regards to the rather fast regrow of plants and trees. The plants are taking up CO_2 from the air and this is released into the atmosphere when combusted. In order to be CO_2 neutral, re-planting must occur continuously. Large forest fires can abstrict the CO_2 stored in the biomass of the forests much faster than it otherwise would be, and from a greenhouse-gas perspective this is a considerable risk. The combustion of biomass and biofuel is also a large contributor to acidification when sulphur dioxide and nitrogen oxides transmute to acid rain in the atmosphere. Here the methods of combustion, as well as the access to flue gas purification, are of great importance for the environmental impact of the combustion. Wind power may be very clean, but it nevertheless often meets harsh opposition in local areas. Neighbours worry about disturbance from noise and nature enthusiasts complain about negative impact on scenic landscapes. Since electricity cannot be stored per se[2], the quota of, for example, wind power, solar power and wave power in the electricity systems is limited due to the need to keep power balance in the electricity grid. Due to weather fluctuations, the dependence on other energy sources in the electricity grids is evident.

More objections to the overall benefits from renewable energy sources could be stated – they all contribute to the conclusion that all energy use today (aiming at the whole chain from resource exploitation, to energy production, distribution and finally energy use) has some environmental impact, i.e. land use affecting wild life, ecosystems and biodiversity, green-house gas emissions assumingly affecting climate, acidification of lakes and waters, eutrofication, health problems from particles, and so forth[3].

Both energy efficiency and renewable energy basically mean making improvements through the use of incumbent technologies or materials, or to invest in new technologies. For a household, this could mean changing the heating system, investing in new triple-glazed windows, insulating the roof, or the like. For energy producers this could mean investing in technologies to raise the degree of efficiency in the heat or power production, or to use pipes with better insulating capacity in the district heating grid.

Related to energy efficiency is the issue of "Negawatts", a concept that was introduced by the American physicist Amory Lovins in 1989. A Negawatt is the saving of a megawatt of power

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[2] Electricity cannot be stored per se, although water for hydro-power can be stored in reservoirs, and for short-term use, batteries, fuel cells, condensors and flywheels can be used (IVA, 2002)

[3] Also from a social aspect of sustainable development, the use of ethanol as biofuel has been debated, imported from areas with bad service conditions, like for the workers in the suger-cane fields in Brazil.

by reducing consumption or increasing efficiency[4]. By creating a market of negawatts one can make saved electricity behave like a commodity. One way to do this is with a competitive bidding process, which was first used by the Central Maine Power Company in the USA (Lovins, 1989). Here, customers come up with energy efficiency measures or savings that they can sell to the utilities. Today, these measures are part of what is referred to as Demand Side Management (DSM) or Demand Response (DR). Demand side management will be further elaborated in chapter 6. Lovins means that energy efficiency has an enormous potential because it is very cost-efficient compared to the alternative – investing in new power plants.

The construct *energy conservation* either means energy efficiency or energy savings made through behavioural changes. Energy conservation done by end-users in line-bound systems will result in yet much bigger savings in primary energy[5]. This is due to the losses that occur in the chain from energy extraction from natural resources, in energy production, conversion, distribution, and finally in the utilisation of appliances and installations. Energy conservation measures, together with the substitution of energy sources (like converting to renewable energy systems), are the measures used in *energy economisation.*

1.1 Objectives

The title of this thesis is "Energy services in Sweden – customer relations towards increased sustainability". The energy services referred to here are the supply of electricity and district heating. This means that they are grid-bound services supplied within large technical systems (in Hughes terminology[6]). In the discussions about technology-behaviour interaction, there is typically an overemphasis on technical development, while daily use, maintenance and operation get far less attention (Van Vliet, 2006). Changes to a more sustainable energy system include as major actors *the users* of the services. Hence research about customer preferences, decision-making and responses are of great importance when trying to implement innovative systems, new measures or services.

This thesis will give some examples of studies carried out within the field of energy economising, either by energy conservation, energy efficiency or by substitution. The emphasis of these studies is on the relation between electricity or district heating utilities and their household customers. The set of relations under study is demonstrated in Figure 1.

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[4] http://www.sustainabilitydictionary.com/n/negawatt.php, downloaded 31 March 2008.

[5] Primary energy is energy that has not been subjected to any conversion or transformation process. Source: http://en.wikipedia.org/wiki/Primary_energy (downloaded 2 April 2008). But primary energy is also, somewhat confusingly, used as "the total amount of energy that is required to produce one energy unit from extraction of natural resources to delivered energy service". This confusion would be avoided if a distinction between *primary energy* and *primary energy use* could be made.

[6] See Thomas Parke Hughes (1983) *Networks of Power. Electrification in Western Society, 1880-1930.* John Hopkins University Press, Baltimore.

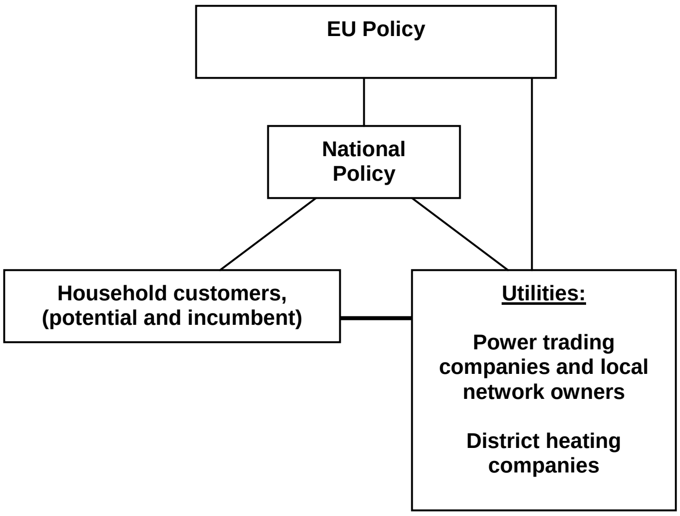

Figure 1: Set of relations under study (based on Chappells et al. 2000, p 5).

The studies are looking into some problems or concerns that the energy companies are facing and that influence their business or system efficiency. These problems or concerns fit into three categories:

- Electricity peak load problems and load management in households
- Energy monitoring and feedback
- The selling of district heating to households in detached house areas

Since most electricity utilities (power trading companies or network owners) and district heating utilities in Sweden are profit-making companies[7] (i.e. joint-stock companies, owned either by the municipalities, private, international actors or the state), their priority is to earn money for their owners. All measures, offers or proposals to customers taken on by the utilities must therefore consider profit-making. How then, will sustainability — which is proposed as an indicative term in the title of this thesis — fit into this picture?

Firstly, social scientists within the field of ecological modernisation would say that a complete neglect of the environment is no longer accepted as a legitimate position for energy utilities or other industries (see Spaargaren and Mol, 1992; Hajer, 1995: in Mol & Sonnenfeld, 2000) and that the contradistinctions between *industrial modernity* and the antithesis *ecological counter-modernity* are transformed into a new kind of modernity – that of ecological modernisation (Anshelm, 2000). The pressure on energy companies to act sustainably, however, still comes from national, regional and supranational governance in society and, to a certain extent, from the customers themselves.

Secondly, all three categories above fit into the concept of energy economising, which was argued above to be a crucial part of a sustainable development. Load management can

[7] Although, there are still a few district-heating utilities that are administrated at as municipal service.

enhance system efficiency and help to avoid investment in new power plants and new enforcements of the electricity grid; energy monitoring and feedback can contribute to energy conservation and new energy services for household customers; and substitution of oil and electricity to district heating is considered to be environmentally beneficial.

The overall objective of this thesis is to study how customers respond to utilities offers, proposals or energy services on the Swedish electricity market and heat market concerning load-management in households, energy feedback to household customers, and the offers directed to households in detached houses to convert to district heating.

In each of these fields, specific research questions and problems are raised; the specific aims of the included studies are described in the following subchapters.

1.1.1 Peak load problems and load management

Peak load problems occur in the electricity networks (and other networks, too) due to either insufficient electricity production or insufficient transmission capacity. Where the problems traditionally have been tackled on the supply-side through the construction of new power plants and reinforcements of the electricity grid, solutions on the demand-side can enhance system efficiency by avoiding such investments. Due to the deregulation of the electricity market, the production reserve capacity has diminished[8] rather than increased in the Swedish electricity system and for this reason, there is an enhanced national interest in finding solutions on the demand-side. The operator of the Swedish electricity grid, Svenska Kraftnät, today stockpiles a load reserve, but in the future, solutions are thought to be market driven. This, together with the plans for decommission of Swedish nuclear power plants, makes the issue highly topical. For local actors on the electricity market there are various reasons to develop methods in order to influence the load patterns of the customers. In literature these methods are generally called *load management.*

The momentary electricity use in households, what could be referred to as “load behaviour”, has not been problematized in previous behavioural studies of energy use. One aspiration of this thesis is to contribute to the knowledge of electricity and load consumption in electric heated houses. Since household customers are end-users in the electricity system, time of use in energy consumption becomes interesting in terms of load problems.

A closely-related aspiration of this thesis is to contribute to the knowledge of customer comfort, acceptance and behaviour to load management, since this also is a neglected research area of load management. Although there are quite a few studies in Sweden, as well as in other countries, which focus on load management, the emphasis in these studies has mainly been on technical functioning and economic potentials, not on customer aspects.

[8] The reserve power plants that existed before the deregulation – mainly oil condense power and gas turbines – where not reckoned to motivate their own costs any longer, since they were seldom used (The Swedish Energy Agency, 2003)

Three papers in this thesis aim to contribute to this field:

- Paper II: Pay for Load Demand. Electricity Pricing with Load Demand Component
- Paper IV: Turn Me On, Turn Me Off! Techno-Economic, Environmental and Social Aspects of Direct Load Management in Residential Houses.
- Paper V: What's on the top? Household load patterns and peak load problems.

1.1.2 Monitoring and feedback

Energy savings from informative billing were shown in Norway in the end of the 1990s (see Wilhite et al, 1999). Norwegian legislators decided that at least quarterly meter readings and billing based on actual use should be introduced to household customers with an energy use over 8000 kWh/year. Influenced by the actions realized in Norway, and later by the EU directive 2006/32/EC (see Appendix A), the Swedish government has taken interest in energy monitoring and feedback for a long time now. This has lead to a new law about monthly electricity meter readings for household customers, which will come into force 1 July 2009. Installation of more than five million electricity meters will have taken place by July 2009 (Göransson, 2006). The objectives of the law that concern customer relations are (inter alia):

- Enhancement of customer comprehension of the electricity bills through the abolishment of billing with yearly set-offs; better understanding of own consumption; decreased demand for utility customer services.
- The monitoring can work as a basis for more informative electricity bills, which in turn will lead to an estimated energy conservation of about 2- to 3% (provided that the bills are based on actual use and include statistics about the household energy use).
- New development of electricity and network tariffs that better reflect peak-load costs that will lead to more efficient electricity use.
- Improved electricity market – customer changes in electric retail company are expected to work better (smoother for customers and less expensive for companies).
- The new possibilities from installations of electricity meters can work as a basis for innovative energy services to customers
- Improvement of information on power outages due to better error-recovery procedures and a source for calculation of customer compensation in power outages (Göransson, 2006).

The dominating aspect of new electricity meters will be two-way-communication and technical features for collecting hourly values. The share of one-way-communication meters is assessed to be low, about 10%. Two-way-communication enables more sophisticated load-management of customers' load, but this feature does not seem to be installed as a standard, just maintained as a possibility if the customer wishes to have this as an energy service (ibid).

One paper in this thesis is contributing to the knowledge about customer preferences regarding the electricity bill; another paper discusses the possibilities and the benefits of using the valuable data from hourly metering that is (or soon to become) accessible for many electricity utilities.

The papers included in this field are:

- Paper I: Bill Me This Way! Customer Preferences Regarding Electricity Bills.
- Paper VI: More or Less about Data – Analyzing Load Demand in Residential Houses.

1.1.3 Selling district heating in detached house areas

District heating is considered to have many economic and environmental advantages, making use of waste heat and troublesome fuels like garbage incineration and biofuels. This central, large-scale production of heat is more efficient in terms of the thermodynamic qualities (degree of efficiency), the environmental qualities (low emissions) and economic aspects (profit) compared to small and scattered heat production. If detached houses with electric heating are converted to district heating, some peak-load problems in the electricity grid can be avoided. Local environmental problems of bad air quality from wood burning can also be solved if households in these areas can be persuaded to adopt district heating instead. The deregulation of the electricity market has lead to a decrease of the margin for investments in new power plants. In order to build new CHP-plants (combined Heat and Power plants), heat demand has to rise accordingly, and here, the detached-house sector can serve as a new heat demand.

The Swedish district heating industry is, and has always been, working within the border area between public administration and commercial business on a more or less competitive market. The district heating industry has, in different ways, taken on a societal responsibility and intermittently it has benefited from certain governmental economic support (even if examples of the opposite situation can be maintained, for instance the way in which combined heat and power has been taxed). In later years, a more market-focused thinking has appeared.

Many district heating companies are today expanding in detached housing areas, but there are also those who do not consider this market segment profitable. Access to large quantities of cheap heat energy, for example industrial waste heat, or propitious land conditions, can constitute a natural background for expansion, but the degree of commercial direction in the company seems to be as important in this context. Even if the district heating industry cannot be said to lack business-likeness, there are substantial gaps in the marketing strategies, which can be related to the many years of business with relatively little competition and a predominant focus on techno-economic matters[9].

The studies in this thesis regarding the selling of district heating to households in detached detached-house areas have been looking at the expansion strategies for Swedish district heating companies, and how customers are deciding upon an offer of conversion to district heating in a specific detached-house area in Southern Sweden. Among the two studies of

[9] The text about district heating in this subchapter is influenced by an application of research grants made by the research group for the study published in Paper III.

district heating in this thesis, the first one is aimed at finding out what kind of strategies the Swedish district heating companies have for expansions to low heat-density areas; what kind of information the companies gather about their potential customers; what facts they base their decisions on for selection of prospect areas and for marketing purposes; and what sales activities are used to obtain a high rate of connections.

The second study of district heating aims to investigate one Swedish district heating company's marketing activities and expansion strategies in a detached-house area where the customers were offered conversion of their direct resistive electric heating into district heating. The objective of the study was to investigate the decision-making process in the households and learn about the factors that influenced the households to accept or reject the offer.

Papers included in this field are:

- Paper III: District Heating Expansion Strategies in Detached House Areas
- Paper VII: Make the heat hotter! Marketing district heating to households in detached houses.

1.2 Limitations

A few important limitations of this thesis should be mentioned.

Firstly, the studies included in this thesis focus on Swedish electricity companies (either power trading companies and network owners), district heating companies, and the household customers of these companies. The national perspective implies that Swedish prerequisites are built-in to the research. This will affect the generalizations that can be made from the results in the studies, something that will be discussed in the method, see chapter 4.

Secondly, the customers referred to in this thesis are household customers, and the main focus is on households living in detached or semi-detached houses – homeowners. These household customers experience more control over their energy situation than do household customers in apartments. This is due to the fact that they are paying for their own usage of heat and hot water and that they have the possibility to invest in new equipment (for example white goods) or improvements to the climate shell of their houses. They also have the responsibility to make repairs. Altogether this means that these households usually have larger energy bills and that they are more interested and knowledgeable in energy-related questions than other households.

Thirdly, the household customers' energy use can be divided into direct and indirect energy use, where indirect energy is the energy needed for producing the commodities or services bought and used by the households. The direct energy use is the energy that households use for heating, lighting, cooking, washing and personal transportation (Carlsson-Kanyama & Lindén, 2002). The studies in this thesis are all referring to the households' direct energy use, with an exception for personal transportation.

Finally, studies were carried out in a trans-disciplinary field where technical, economic, social and environmental perspectives were all included. The research questions stated in the different studies are therefore viewed from a broad perspective and this approach might sometimes be taken on at the expense of the depth in the particular fields.

2 Energy markets

The energy markets referred to in the title of this chapter are the Swedish electricity market and heat market. Many different actors exist on these markets. In the electricity market, the special interest in this thesis is in the power-trading companies and the local network owners and their household customers. In the heat market, the emphasis is on district heating companies and their (potential) household customers.

The markets for electricity, district heating and also natural gas are interacting to some extent[10]. Natural gas can be used to produce electricity and district heating, and electricity can be used in the production for district heating (usually by the use of heat pumps). It is rather common that the same corporate group engages in all three markets (Stadskontoret, 2003).

2.1 The Swedish electricity market

The Swedish deregulated electricity market consists of many separate companies that can be divided into the following categories[11]:

- Electric *producers* are actors connected to the power system that produce electrical power. The producer is the supplier to the power-trading companies.
- The *network owners* (network companies) are the owners of network facilities and have the concessions for the facilities. The network owners are responsible for transmitting the electrical energy from the production plants to the consumers. This is achieved via the national grid[12], the regional networks and the local networks, which are all owned by different network companies. The regional networks transmit power from the grid to the local networks and sometimes to large consumers, e.g. industries. The local networks distribute power to the consumers.
- The *power-trading companies* (also referred to as *electric retail companies*) can have the roles of power trading companies, electricity suppliers and balance providers. Both network owners and power-trading companies are sometimes referred to as *utilities*.
- Final *electricity consumers* (end-users) can be everything from industries to households. The consumers must have an agreement with an electricity supplier in

[10] Natural gas is only extended to the southern parts of Sweden, and is therefore not as commonly used by household customers as in the rest of Europe.

[11] This description is based on information from Svenska Kraftnät: http://www.svk.se/web/Page.aspx?id=5219, downloaded 12 April, 2008.

[12] The Swedish electricity grid is divided in three levels: the national grid with electric mains of 220 to 400 kV, regional networks of 130, 70 or sometimes 40 kV, and local networks of 10 down to 0,4 kV. Source: IVA, 2002.

order to be able to buy electricity, and hence they can also be called *customers* in their relation to network owners and power-trading companies.

- The system administrator or *system operator* (Svenska Kraftnät) ensures that production and imports correspond to consumption and export, and that the Swedish electricity system's plants work together in an operationally reliable way.

The deregulation[13] of the Swedish electricity market was initiated in 1996. By 1999 all household customers had the possibility to make cost-free shifts to optional power-trading companies on the market. According to the trade organisation Svensk Energi (Swedish Energy), the most important aim of the deregulation was:

> "to remove the impediments for enhanced mobility among customers with low electricity use and thereby obtain enhanced competition and price pressure on the market" (Svensk Energi, 2000).

The deregulation has opened up a competitive market, which has forced the electricity companies to focus on three new perspectives:

1. The role of the electricity company has changed from that of being the provider of public services. Instead they have now become *competitive companies* with a need to profile themselves when trying to establish a good image.

2. The undifferentiated service of electricity now has to be differentiated and conceptualised, so that it will show competitive advantages compared to products from competitive power-trading companies, in order to attract and keep the customers.

3. The view of the electricity users has to change from that of merely being a load in the system to being seen as customers with different preferences, prerequisites and values. This has put the focus at enhanced customer contact and the possibilities of segmentation of customer groups.

Similar influences from deregulation are also shown in other European countries that have liberalized their electricity markets. Markard & Truffer (2006) conducted an interview study with utilities from Germany, the Netherlands and Switzerland[14]. From the interviews in this study they draw the conclusion that innovations at company-level had changed after the liberalisation of the electricity market. Under the monopoly conditions, technical aspects were highly in focus because the decision-making was directed at high quality of power supply. Rather than developing new technologies, the incumbent ones were enhanced and the innovations needed to be compatible with existing supply systems and established engineering practices. Furthermore, the innovations had to fit existing organizational structures and were mainly based on existing resources and competences.

[13] In English speaking countries this is sometimes referred to as *restructuring.* Also the concept *liberalisation* is commonly used.

[14] They conducted 44 interviews in more than 30 utilities.

After the liberalisation, the focus changed to cost efficiency and customer service orientation. Product differentiation and the diversification of business fields became increasingly important. Innovation projects often were designed in a way to strengthen co-operations and strategic alliances with other utilities and manufacturing companies (see Table 1).

Table 1: Changes in the selection environment at the firm and sector level – monopoly vs. liberalized market (Markard & Truffer, 2006).

Monopoly	Liberalized market
Selection criteria (firm level)	
Costs and quality	**Costs and quality**
Does the innovation contribute to the technical quality of power supply? Does the innovation improve established technologies?	Does the innovation contribute to cost reductions? Is the new product of interest for the customers? Is there a potential to develop a new business field?
Innovation characteristics	**Innovation characteristics**
Is the innovation compatible with existing regimes? Does the innovation comply with the interests of other business units of the (vertically integrated) firm? Can the innovation be integrated into the organization structures of the firm?	Do competitors pursue similar innovation activities? Are the policy incentives to invest in a novel technology? Has the new technology a rather low degree of capital intensity?
Competences, learning	**Competences, learning**
Can the innovation be realized with the existing resources and competences of the firm?	Does the innovation support strategic co-operations? Does it contribute to the development of new competences?
Selection mechanism (sector level)	
Role of consumers	**Role of consumers**
No or little influence on innovation process, consumer interests were indirectly mediated by public authorities	Influence on innovation on the basis of the electricity purchase decision More intense communication between suppliers and consumers
Regulation, policy making	**Regulation, policy making**
Innovation processes influenced by price and tariff system regulation, various environmental policies, sometimes even particular interests at the local-regional level	Price and tariff regulation mostly removed, environmental policies remain, new regulations with regard to consumer protection, market transparency and competition enhancement
Innovation diffusion	**Innovation diffusion**
Innovation management, influenced and often coordinated by associations at the second level, widespread and deliberate knowledge dissemination among firms, replication spatially restricted	Not coordinated anymore, reduced knowledge exchange among competing innovators, no restrictions for replication

For electricity suppliers, the deregulation resulted in the necessity to divide the companies into two legal entities: network owners and power-trading companies. Customers can now choose to buy electricity from whichever power-trading company in the country they like, but they are still directed to the network owner that has concession in the geographical area the customer is situated in. There are many cases where the same corporate group owns both the network and the power-trading company. Some synergetic effects can arise from this relation, but at the same time, if customers are dissatisfied with their network company, they can "punish" the corporate group by buying electricity from another power-trading company outside the corporate group.

The deregulation of the electricity market has led to a reduction in the number of companies active on the market. The market concentration is high on the Swedish electricity market, dominated by three big actors: Vattenfall, E.ON and Fortum.

In 2006, Vattenfall had 45% of the market shares, E.ON 21% and Fortum 19%, adding up to about 86% of the markets shares on the wholesale market. For the Swedish electricity retail market E.ON had 16%, Fortum 14% and Vattenfall 13%, adding up to about 43% of the market shares (Konkurrensverket[15], 2007). For the retail market, the consumers are nevertheless presented with a significant choice of suppliers.

But consumers should not only choose between a number of electricity retail companies, they must also decide what kind of contract they would like to sign. According to Olsen, Johnsen and Lewis (2006), the most common supply contracts offered to Nordic households are:

- The traditional contract. This is sometimes referred to as the "standard variable" or "list" contract where the supplier may adjust the contract price when he finds that appropriate, for instance, following changes in supply costs.
- The market-based contract, where the price directly reflects the Nord Pool day-ahead spot price plus a margin or some other kind of commission.
- The fixed-price contract where there is a fixed price for an agreed period of time, most often one to three years but sometimes longer.

Despite the broad range of companies and contracts to choose between, the Energy Markets Inspectorate[16] argues that there are indications that the competition on the retail market in Sweden should have to be strengthened, for three reasons:

- The market concentration is relatively high.
- There are significant price differences between standardized contracts and variable price.
- The retail margins in Sweden have increased and are higher than those in Norway (The Energy Markets Inspectorate at the Swedish Energy Agency, 2006).

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[15] Swedish Competition Authority

[16] The Energy Markets Inspectorate was set up by the Government on 1 January 2005 as a part of the Swedish Energy Agency. From the 1st of January 2008 the Energy Markets Inspectorate is an authority of its own.

The market concentration has not decreased today. There are those who believe that the Swedish electricity market is working fairly well, but there are also many opponents[17]. The Swedish historian in Economics, Mats Bladh, states that the deregulation of the Swedish electricity market was guided of the beliefs of a “utopian consumer”:

> “This imagined consumer doesn’t have any troubles whatsoever with searching information to be able to choose contract and power-trading company. This information search is carried out painlessly and without time requirement. Even if it is only about a few Euros per year in savings, the consumer is willing to act. The utopian consumer is also extremely price sensitive, which makes the variations of the electricity price seem like an important mechanism for tuning the supply and demand together. This picture of the consumer is invented within a specific economic theory approach. The picture was taken over by politicians and experts that decided and designed the reformation of the electricity market”. (Freely translated from Bladh, 2007, p.12)

Electricity is generally a low involvement service where the customer has rather little interaction with the utility. The only apparent contact that most customers have with their electricity companies is when they pay their electricity bill. It is only in the situations where the service is not functioning properly, such as when there are power outages or when given an incorrect invoice, that the customer turns to the provider. As long as everything is working properly the customer is neither content nor discontent, the relation is however strengthened over time.

But when something happens that gives the customer reason to contact the provider, there is a risk that this contact can result in a negative change in the relation (the customer changes attitude towards the provider that in some cases make the customer leave the company). Therefore, it is very important that the provider in every contact with the customer is acting to strengthen the relation to the customer, by listening and believing in the customer and by handling the issue quickly and correctly. In case of inaccuracies it is important that the provider apologise and preferably compensate the customer (Nyberg, 2002).

[17] For a gathered view of 21 Swedish persons in the field of electricity supply (i.e. CEO:s of electricity companies, researchers, politicians etc.), see Lunds Energi Koncernen (2007) *Marknad på riktigt? 21 perspektiv på elmarknaden* (Market for real? 21 perspectives on the electricity market). Wallin & Dahlbom, April 2007.

2.2 The market situation for Swedish district heating companies

The relation between the district heating companies and their household customers is similar to the one between electricity companies and their household customers in sense that the district heating is also a low-involvement service, implying that there is not so much contact between companies and their household customers. But there is one essential difference: district heating constitutes a local monopoly in the sense that there is just one supplier in the (local) district-heating grid. For customers, the connection to the district-heating grid contributes to a "lock-in" because of the rather high investment costs paid for the connection and the district-heating substation[18]. Once connected to the district-heating grid, the customers have to rely on the price setting from the local supplier.

The energy prices for district heating are varying over the country and the highest price can be as much as double the lowest price. The dispersion around the mean-value though, is rather small depending on the relatively small number of companies with extremely high or low prices (The Swedish Energy Agency, 2005). For the past several years the question of establishing a new regulatory agency for surveillance of the district heating prices has been on the government agenda, to protect customers from brute pricing. A new government bill (Näringsdepartementet: Prop. 2007/08:60) from the Ministry of Industry, Employment and Communication is proposing a new district heating law. The new law implicates, among other things, that the district heating companies will be obliged to negotiate with their customers about specific contractual stipulations for district heating. If the parties cannot come to an agreement, they can apply for arbitration from a conciliation board. The government bill also contains customer protection from distribution interruptions, but nowhere is there written any stipulation for price probation.

For installations of new heating systems in detached houses, the district heating companies cannot be said to have a local monopoly. When trying to convince household customers to connect to the district-heating grid, they are competing with other actors on the heat market. Here they have a competitive disadvantage (partly together with other line-bound alternatives), when the prerequisite for district heating only can be given through an expansion of the district-heating grid. Due to large construction costs and significant heat losses in the distribution, cost-effective heat production is required. Furthermore, it is essential that the heat demand in the area turn out to be as big as possible. This necessitates that as many households as possible, in the given area, are convinced to adopt district heating. Hence, the selling of district heating cannot be carried out sporadically to geographically scattered customers, which is the case for some of the district heating companies competitors, such as vendors of heat pumps, boilers and other heating systems.

[18] The substation is basically a heat exchanger that is used to separate the customers' water system from the district heating system.

2.3 Energy policy

Energy policy at the national level or EU-level is influencing the market situation and the relations between utilities and customers. The European parliament and the council of Europe issue directives for its member states and the latest directive concerning sustainable energy development was directive 2006/32/EG concerning efficient energy use and energy services. According to this directive, the member states should develop national action plans for energy efficiency measures. In March 2007, chiefs of state or heads of government in the EU emphasized the need to enhance the energy efficiency in order to achieve the savings requirement of 20% of the primary energy use (SOU 2008:25).

Different kinds of management control measures are used at the national or European level, which enforce the conversion to a more sustainable energy system. Some examples are shown in the following list (Swedish Energy Agency, 2007):

- The European Union emission trading system was introduced in 2005.
- The system of electricity certificates was introduced in 2003; this control measure is aiming at increasing the use of electricity from renewable energy sources with 17 TWh from 2002 year's level to the year of 2016.
- Measures for more efficient energy use, competitive technology purchasing and market introduction of energy efficient technologies are carried out on the national level.
- An investment subsidy for converting space heating and hot water systems running on oil and electricity in detached and semidetached houses or certain premises, was introduced by the Swedish government for the years of 2006 to 2010.
- The existing climate investment programme (KLIMP) has been toned up for the years of 2007 and 2008.

The list doesn't include all control measures influencing utilities and consumers of electricity and district heating, but it gives a good picture of what is emphasized in the Swedish energy policy at present time.

3 Theoretic approach

This chapter describes three theoretical areas that will be applied to the studies included in this thesis. The three areas are:

- Socio-materiality in energy systems
- Consumer behaviour and the model of social practices
- Feedback

3.1 Socio-materiality in energy systems

> "All relations should be seen as both social and technical./.../ Purely social relations are found only in the imaginations of sociologists, among baboons, or possibly, just possibly, on nudist beaches; and purely technical relations are found only in the wilder reaches of science fiction."(Law & Bijker, 1992, p. 290)

Modern society involves living in a human-built world, where technical artifacts make up most of our ambient environment, especially in cities. In a very intriguing chapter of the anthology "The Sociology of Consumption", Per Otnes (1988) writes about the socio-material collective systems that are underpinning private life in terms of housing consumption. Just think of all the activities that we engage in our homes, our work places and in society in general. In the morning we wake up by the sound of the clock radio. A radio show is going on, connecting us to the first collective socio-material system this day, the radio system. We get up, go into the bathroom and turn on the light, use the toilet, flush it and wash our hands in the washbasin. This connects us to three other large systems: the electricity system, the sewage system and the waterworks. The story can go on, but the reader probably already gets the idea. Otnes states that substantial parts of housing consumption *"in actual fact consists of being served by, and serving, a number of essentially collective sociomaterial systems. In other words, housing consumption consists, to a large extent, of the competent, knowledgeable use and maintenance of such systems"* (Otnes, 1988, p 120).

By this he implies that we are interacting with the systems, and in order to use the systems, we must have or gain some knowledge of how to make use of the systems. What Otnes refers to as socio-material collective systems, the American historian Thomas Parke Hughes (already in 1983) referred to as "large technical systems" (LTS), in his book *Networks of Power: Electrification in Western Society, 1880-1930*. LTS rapidly became a subdiscipline of the history of science and technology. Hughes introduces a double-sided denomination of the term "system": on one hand the system is technical and the different physical components are connected through cables (or pipes or the like), on the other hand there is a social side where a founder is creating all the components needed and bring in more interested actors in the development of the system.

Electricity and district heating systems are characteristic examples of large technical systems, or LTN – Large Technical Networks (a distinction made by Joerges, 1988, for different types of LTS). Although the definition of LTS emphasizes physical components and machinery, these systems also include non-physical artifacts like regulations and norms; different kinds of actors, e.g. utility companies, network operators, manufacturing firms, investors and users. Furthermore, different kinds of standards including technical and social norms, organisational practices or usage patterns co-evolve with the development of the system and assure the compatibility and inter-operability of the systems numerous components (Markard & Truffer, 2006).

Large technical systems are interdependent. Failure of one system can cascade throughout the network complex (Hughes, 2004). The loss of electric power will effect many other systems, among them district heating supply, due to the fact that today's district heating system cannot work without electric pumps. In order to enhance customer comfort and security in large technical systems, measures should be taken to assure customers electricity, heat and hot water at all times (possible).

Markard and Truffer (2006) argue that the high degree of interdependency and the existence of powerful standards impede transformation in the system, and a novel product must not only meet customer needs, but also be compatible with the existing infrastructure and technical norms. *Reverse salients* is another central concept in Hughes terminology of LTS. By reverse salients he means front sectors in the developing system where there are troubles or where a strong opposition is prohibiting further development. One example of a reverse salient in the development in the electricity system is the competing interest in land use when trying to find areas for erection of new wind power plants (se for example Carlman, 1990).

Technical style is another critical factor in LTS, where distinct differences in technical style can be shown when comparing large technical systems in different countries (as Hughes found in his study about electrification in Germany, the USA and England). For district heating, different technical styles can be shown comparing one-pipe systems in the former Soviet Union and Iceland with the more common 2-pipe systems in Sweden. There are also examples of 3- and 4-pipe systems in Sweden and elsewhere. Another example is the prevalence of district-heating substations for Swedish customers, but not for Danish customers[19]. Therefore, comparisons of energy provision between different countries or different networks must take into consideration the different kinds of regulations, technical styles, standards and organisational practices that occur in the different cases.

[19] The substation is basically a heat exchanger that is placed in the customer dwelling, separating the customer system from the district heating system. In case of leakage inside the dwelling there is no risk for submersion since the customer water system does not contain that much water, wheras without the heat exchanger the water from the district heating system can continue to flow until the leakage is discovered and repaired.

The subject of load management is one of the different research areas covered in this thesis. Load management is an important measure to solve peak load problems and peak problems are recurring problems noticed in large technical networks:

> ”Control problems typically arise from a-synchronical changes on the part of diverse operating agencies, or diverse users, or *between* operators and users. The latter is of special interest because here highly variable user styles, particularly in informal everyday life settings, tend to clash with highly formalized operating and control styles. Thus, issues of load management run through the history of most LTN.” (Joerges, 1988, p 27).

Since the components of the system make up physical barriers restricting the supply, the level of the highest peaks needs to be taken under consideration when dimensioning the system. If the users are included within the system borders of the electricity system (or other large technical networks), demand side management (DSM) can also present a possible tool for load management.

The constructs used in the theories of LTS emphasize the socio-cultural aspects of energy systems. This approach can be valuable in the analysis of the different studies in this thesis, which look into every-day practice of energy use in households. Customers of district heating and electricity depend on and adjust to these systems. At the same time, new products and services from utilities should be guided by customer needs and wishes. The theories of LTS can also help proclaim the inertia for changes that exist in the large technical systems.

3.1.1 Invisible energy

Electricity and district heating are collective socio-material systems that we use to fulfil different needs in our daily lives. The distribution, along with the billing and payment for this energy, contribute to the invisibility of these services. The services are often used without much consideration of the expensive technical systems providing them. There are many factors that contribute to making energy invisible. The physical qualities of energy, especially electricity, make it impossible to see, smell, hear or weigh it. Electrons are the same whether the electricity is produced from nuclear power plants, oil-condense power plants or wind power. To differentiate electricity in terms of production, this must be communicated because there is no way for the consumer to determine the origin when using it.

Aesthetical values of interior design make us want to hide pipes, electric wires and devices in our homes. The existing tradition of hiding the heating and hot water systems estranges us from these technical systems. But maybe trends of interior design are now taking another direction. Some new devices with the aim to visualise electricity use have been invented in recent years. Aesthetical values regarding the way the ambient environment is constructed are also considered by most people. Not many people enjoy living nearby heat plants, power plants or electric mains because they think they look ugly or because of fear for accidents, emissions, noise and other quality-of-life issues. Therefore production sites are usually placed away from residential areas. This way of thinking is referred to as “NIABY” (acronym for “Not in Anybody’s Backyard”); a concept that originates from a critical view of the concept NIMBY (Not in My Backyard), where NIMBY stands for a more individualistic perspective, whereas NIABY is an expression for taking responsibility for the common good (Woolsink, 2000).

The energy systems are run and operated by experts. A large part of the technical infrastructure and economic systems that exist behind the wall are not visible to the consumers. If the electricity or district heating system is working without interruptions or outages, this will actually enhance the feeling of taking the service for granted. Since the experts run the systems, it is not the consumers' responsibility to fix broken parts in the system, at least if it is not on the customer side of the electricity meter or district-heating meter. This does not only make the energy supply invisible, but also beyond the consumers' control.

There is no rationing of load or energy use for the household customers in the Swedish electricity system. The main fuse-level restricts the total power-load possible to use in the household. This level is often quite generously dimensioned because it allows the households to run several electrical appliances at the same time, and hence, the ceiling of this fuse-level is seldom reached. For district-heating customers, the district-heating substation makes up the limit for heat and hot water use. Well-functioning district-heating systems should be generating good heat and hot water comfort for all their customers, as well as the ones in less dense areas. The volume of hot water use is normally less limited in households with district heating than in households with electric domestic hot water heaters with (small) storage tanks.

3.2 Consumer behaviour and the model of social practices

Consumer behaviour is a very broad research field with roots in economy and social psychology, however this theory chapter will emanate from the theory approaches from Shove, Spaargaren and VanVliet. These researchers have studied the specific conditions for consumption in socio-material collective systems like energy, water and waste systems, and formed a theoretic basis of the relations between providers and consumers. By using the concepts of *cleanliness, comfort* and *convenience*, Shove paints a picture of how social practices have changed over time, influenced by the increased access to energy supply. Spaargaren and Van Vliet are using this theoretic approach by Shove and put the social practices into a conceptual model for studying consumption practices.

But first, let us to start with a discussion of what makes services from large technical systems different from other goods and products from other industries, and how this influences the roles of customers.

Besides the invisible and intangible nature of energy described above, there are other peculiar features of services from collective, sociomaterial systems of provision (energy, water and waste services), emphasized by Chappells and colleagues. One feature is that, as argued before, the services or products of energy (water and waste) are essential for many of the basic practices of the households. They *"represent the material and energy flows, which form the material sustenance-base to our daily life"* (Spargaaren, 1997). These products or services cannot be bought in or brought home from a shop; instead they come in a standardised form to our homes through pipes, cables or the like (in standardised voltage, pressure or temperature). This makes them highly uniform, no matter place or time. In many studies it has been shown that prices are relatively inelastic for these types of services and levels of use will only slowly reduce while prices rise. Chappells and colleagues explain this price-inelasticity by way of the fact that some possible uses of electricity, water and waste services (for example heating, drinking and disposing), are so essential that many households would not even consider reducing their consumption even if the price were doubled. Another plausible reason for price-inelasticity refers to the invisibility of energy, and the unconscious use of it in everyday routines that makes it very hard to relate the energy use to the actual costs.

Furthermore, Chappells et al. are emphasizing the fact there very seldom are more than one network for provision of the services in an area, which is due to the large investment costs for building and maintaining the networks. Hence, the consumers are dependent on just one supplier. As a consequence for natural monopolies, the consumers become *captive consumers* (ibid). The role of the consumer in these types of system is rather passive. This captive role of the consumer has changed in some respects after the liberalisation of the electricity market (Van Vliet, 2006). Swedish customers have had the chance to change supplier, that is, the power-trading company, since the end of the 1990s, when the Swedish electricity market was deregulated. Market activity has increased since the initiation of the deregulation, but still more than 40% of the household customers do not change supplier or renegotiate their standard or list contracts (Bladh, 2007). Bladh describes the *thresholds for market activity* as costs, other than economic costs, for the customers. In order to change electricity supplier, the customer must first collect information about other power-trading companies and their agreements. This also implies that they must have a minimum of knowledge about how these contracts cohere and be able to separate grid fee, tax and energy price from each other, because only the price for energy will change when shifting to another power-trading company. Consequently, the deregulation has made it possible for customers to become more active at the market, although this "freedom" is still not used by a large share of Swedish households.

Chappells and Shove also argue that demand-side management can change the role of the consumer (in Chappells et al, 2000). Three key points are made:

- "That consumers are mini-infrastructure managers and network co-providers in their own right and can act as generators, ceiling-setters, maintainers and users;
- That providers are able to set parameters of consumer involvement by careful scripting of storage and efficiency devices (with demand schedules and macro/micro ceilings):
- That the relationships between consumers and the resources on which they depend are influenced by the proximity to and level of particular resource ceilings, and that these ceilings are being radically redefined by a range of new intermediaries and providers within networks." (Chappells, et al, p 101).

In this way, the consumers also take on the roles of system generators, installation engineers, capacity-setters and maintainers, and this challenges the view that consumers do not have any real interest in the finer details of demand management — even if the language of "peaks" and "loads" often fails to interest many households (ibid).

3.2.1 Comfort, cleanliness and convenience

Instead of focusing on environmental behaviour and green consumerism for finding more sustainable ways of life, Elizabeth Shove suggests that the cultural aspects of domestic consumption should be emphasized and explored. By using the concepts of Comfort, Cleanliness and Convenience, she explores the questions of how new conventions become normal, and what the consequences are for sustainability. The areas of the three C's are important since they all require a lot of resources and because all three aspects have been subject to recent and radical change. Shove works on the supposition that domestic consumption practices are not just a combination of objects and systems of provision, but also intimately linked in reproducing what people are referring to as normal or, for them, ordinary ways of life (Shove, 2003).

The environmental challenge is to understand how meanings and practices of comfort, cleanliness and convenience fall into the realm of the taken for granted, and how they change. Shove considers two aspects of change: escalation and standardising. By considering these two aspects she raises these questions: Are the conventions of practices changing in a way that is more resource demanding? Are expectations and practices standardising and converging around the world? If so, what are the environmental consequences?

As an example of comfort, Shove describes how the capacity to control the indoor climate has given rise to a new norm for an "optimal comfort zone" and new standards for heating, refrigeration and air-conditioning.

> "The conclusions of scientific research are embedded in codes and standards that are in turn reproduced in the built environment and in peoples' expectations of what is should be like. By redesigning homes and offices *for* air-conditioning, designers have condemned homeowners and workers to an air-conditioned way of life from which there appears to be no way back" (Shove, 2003, p.399)

These norms and standards make people adjust their clothing accordingly and vice-versa. The ASHRAE Standard 55, based on the equations from Fanger[20], assume that people should be wearing on *cloe*, which corresponds to the wearing of a business suite. Shove describes this development as a ratchet, a device that can only go in one direction (ibid).

Laundry is taken as one example of the concept of Cleanliness. Shove describes how norms of cleanliness have changed from16th century France where changing a shirt took the place of refreshing and washing the body, to today's laundering in washing machines where the meaning of clean clothes also incorporates the feeling of freshness and is in essence a state of mind: "*Knowing things are clean, people feel good about wearing them*". Shove describes laundry as cogs in a system of systems, where stocks of clothing, washing machine design, rationale, skills and expertise constitute different cogs that can spin backwards and forwards. By this parable she wants to illustrate how future norms and standards can either increase or

[20] Povl Ole Fanger was an expert in the field of the health effects of indoor environments at the technical University in Denmark. Source: http://en.wikipedia.org/wiki/P._Ole_Fanger, downloaded 2008-05-05.

decrease sustainability of this social practice. For example, today we (from statistics from USA and UK) do laundry more often than we did in the 1950s, but the water temperatures used have decreased due to better detergents and better washing machines.

Convenience, Shove argues, was adopted in the 1960s to describe arrangements, devices, or services that helped save or shift time. Warde, Shove and Southerton (1998 in Shove, 2003) distinguish between modern and hypermodern forms of convenience, where modern convenience refers to the reduction of time taken to achieve a goal, whereas hypermodern convenience is about storing or shifting time, and thereby people can experience a greater flexibility and control over their schedule. Furthermore, Warde et al. claim "*that convenience is valued and relevant where there are problems of coordination and where individuals are obliged, and have scope, to construct schedules of their own".* Shove uses the parable of a spiral to describe convenience, where she states that:

> "Convenience devices come into their own in helping to create and manage the bunching of activity, but in facilitation multi-tasking or in reducing the time a specific activity takes they can have the affect of further fragmenting components tasks, thereby increasing demand for convenience!"(Shove, 2003, p 412).

What will the environmental impact be from the development and spreading of convenience? This is hard to know, because it depends of how convenience is delivered (ibid). But there are many examples of convenience products that increase the impact, for example convenient foods that require large amounts of energy for preparation, packing material, freezing, thawing etc.

In looking at how norms and standards in social practices are set and have changed over time, Shove has given a valuable contribution to the theoretic development within resource use by putting this use in a socio-cultural perspective where social norms and technical standards influence what is done, how it is done and with what devices. The challenge here is to change the perspective to look forward in order to understand how new norms and new innovations can be applied and dispersed in the future and how these can be influenced, instead of just looking at historical evidence. Shoves' dismissal of the perspectives of green consumerism then seem somewhat too harsh, because these green consumers can participate in influencing future norms and standards in society through making demands on products, and services and on the systems underpinning the social practices.

3.2.2 The chreseology of consumption

The term chreseology derives from the Greek word *chrese*, or *chresimotoio*, which means *use, employ* or *implement* (Otnes, 1988). Spaargaren & Vliet (2000) ordain the research approach of a creseology of domestic consumption, as they are influenced from the theoretic approaches from Otnes and Shove to put the domestic social practices in the context of specific spatial settings and the use of specific clusters of products or services of collective socio-material systems. The settings could be the kitchen, the garden or the bathroom, where the actors make use of the specific tools, for example for cooking or gardening. This creseology should provide detailed descriptions of daily routines of domestic consumption. The benefits from the creseology of domestic consumption that Spaargaren and Van Vliet see, is that this can enhance the knowledge of the ways that *people relate to technologies, households relate to expert-systems and the "private" relates to the "public.*

3.2.3 The model of social practices

Spaargaren & Vliet bring into question that social environmentalist for many years have had a productivist orientation, because the research areas that they have been occupied with are work, factories, labour unions, and the division of labour and the role of technology (Spaargaren & Vliet, 2000). They argue that a stronger emphasis on consumption should be taken on using the social practices model (see Figure 2), where social practices like clothing, housing, food, travel, sport and leisure, for example, should be placed in the centre of the model. This model actually builds on to the theories of comfort, cleanliness and convenience formed by Shove and her colleagues.

On one side of these practices stands the actors that have different lifestyles. On the other side structure, or system of provision – for example, systems for energy, water and waste.

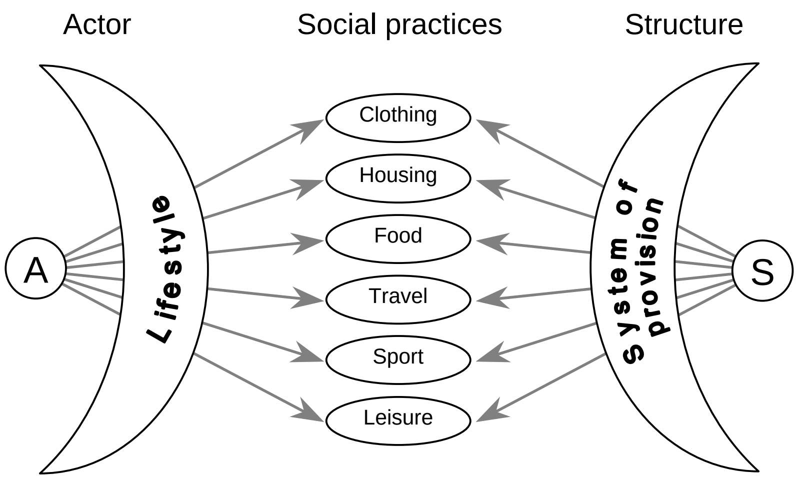

Figure 2: The social practices model (Spaargaren, 2003).

The basic elements of such a model are conceptions of *"domestic consumption", "consumer involvement", "systems of modes of provision" and "environmental innovations"*. These concepts are conceived against the background of changing utility markets.

According to Spaargaren (2003) there are three consequences in the results when using this model in consumer studies, compared to using some variant of the traditional attitude-behaviour model (originated from Fishbein and Ajzen in 1975):

- **The end of the individual as the (only) relevant Unit of Analysis.** In the social practices model, human agency is not analysed in the terms of the isolated individual, but rather in terms of lifestyles and social practices.
- **Environmental policy goals to be defined from a life world perspective.** When using this model it becomes evident that there is a need to reformulate most of the existing targets in policy making. Daily routines like clothing, food, shelter, travel, sports and leisure should be taken as a starting point for policymaking. These policy definitions must be reformulated and specified from a life-world perspective

in order to be recognized and taken on board by concrete groups of citizen-consumers.

- **Contextualizing individual responsibility for environmental change.** By studying environmental change from a life-world perspective, the responsibility of the individual towards environmental change is analysed in direct relation with social structure, and hence this responsibility becomes clearer.

Concretising energy use or other resource use to an everyday level of social practices can help us understand how and what can be changed and with what means. Relating the energy use to specific activities is also an important piece in the puzzle to understand how load patterns can be changed and how demand-side activities can be planned to fit into the real life of household consumers.

3.3 Feedback

Feedback is important in making energy more visible and more amendable to understanding and control (Darby, 2006). In Darby's research review on metering, billing and direct displays, she argues that:

> ”...clear feedback of energy use in households is a necessary element in learning how to control fuel use more effectively over a period of time”.

The use of energy is, to a great extent, embedded in our daily routines. The intangible and invisble nature of energy argued above, contributes to the need for feedback, and feedback and information can work as a means to visualise energy production, distribution and consumption to consumers. Feedback on energy use can also be utilized by utilities for the different reasons that will be addressed in subchapter 3.4.3 about Monitoring and Billing).

3.3.1 Feedback and household energy use

The concept of feedback is often used for describing the output of a system or process, like in the definition from the Oxford English Dictionary where feedback is defined as:

> ”Information about a result of a process or action that can be used in modification or control of a process or system/.../especially by noting the difference between a desired and an actual result.”

Or the following definition that is taken from The Free Dictionary[21]:

1)
   a. The return of a portion of the output of a process or system to the input, especially when used to maintain performance or to control a system or process.
   b. The portion of the output so returned.

2) The return of information about the result of a process or activity; an evaluative response.

[21] http://www.thefreedictionary.com/feedback. Downloaded 14 april 2008.

Looking at feedback as the return of a process or system, it becomes evident that this process and system should be defined in terms of household energy use, that is, to decide the system borders and define the time scope of the process. These considerations, however, are not explicitly made in studies of feedback of household energy use.

The process of energy use in households can be argued to either refer to just one activity that involves energy use, or the many activities or uses that contribute to the total energy use in the household within a certain time span. In addition, a time perspective needs to be established for the process.

The system of household energy use can be argued to involve the user, the appliances used and the dwelling (that is, from the wall socket to the user), or the whole energy system that is required to produce the service (from the ruption of raw material and every part included on the way up to the user). Compared with the discussion of primary and secondary energy use brought up in Chapter 1, this raises the questions of what the feedback should reflect and how the feedback can be attained.

Darby makes a list of different types of feedback (see Table 2) that have been showed in the various studies in her research review from 2006.

Table 2: Different types of feedback (Darby, 2006).

Direct feedback: Available on demand: Learning by looking or paying

- *Self-meter-reading*
- *Direct displays*
- *Interactive feedback via a PC*
- *Pay-as-you-go/keypad meters*
- *"Ambient" devices*
- *Meter reader with an adviser, a part on energy advice*
- *Cost plugs or similar devices on appliances*

Indirect feedback – raw data processed by the utility and sent out to customers. Learning by reading and reflecting

- *More frequent bills*
- *Frequent bills based on readings plus historical feedback*
- *Frequent bills based on readings plus comparative/normative feedback*
- *Frequent bills plus disaggregated feedback*
- *Frequent bills plus detailed annual or quarterly energy reports*

Inadvertent feedback – learning by association

- *With the advent of microgeneration, the home becomes a site for generation as well as consumption of power*
- *Community energy conservation projects such as the Dutch "Eco-teams".*

Utility-controlled feedback – learning about the customer

- *Utility-controlled feedback via smart meters, with a view to better load management*

Energy audits – learning about the "energy capital" of a building
Audits may be:

- *Undertaken by a surveyor on the client's initiative*
- *Undertaken as part of a survey for the Home Information Pack*
- *Carried out on an informational basis by the consumer using freely available software, e.g. carbon calculators.*

Apparently, the system borders here for the feedback are clearly secondary energy use, as showed on the meter reader, except from maybe the examples of energy audits (i.e. the carbon calculators). It is also clear that for most cases on the list, the process includes all energy consuming activities in the household at a certain time or time period, except for cost plugs and devices connected to an appliance that directly show the energy use of that appliance.

Darby also makes a distinction of the feedback time period when dividing feedback into direct and indirect feedback. She describes direct feedback as *"the immediate feedback from a meter or an associated display monitor",* whereas indirect feedback is referred to as *"feedback that has been processed in some way before reaching the energy user, normally via billing"*.

Examples of inadvertent feedback (learning by association) are given in Darby (2000):

- When a person moves house or when there are changes in the physical fabric of the dwelling, the new energy-using equipment in the home might provide an opening for effective opportunistic advice.
- When the home becomes a site for generation as well as consumption of power, for example using solar water heaters and photovoltaic arrays, it is likely that this leads to increased observation, which in turn generates new cognitions of energy use.
- The development of community conservation projects has a potential for *social learning.*

3.3.2 Feedback and motivation

According to Owen and Dudley (2007) feedback has two functions: one *informative* function and one *reinforcing* function. Even if Owen and Dudley here refer to communication theories, their distinction is probably valid when it comes to feedback on energy use as well. In order to *control fuel use more effectively*, as Darby declares, the household must know how much energy is used (the informative function). But information itself does not make householders use energy or fuel more effectively. Hence, the feedback is only effective if there are some motivational drives connected to the feedback.

Costanzo et al. (1986) state that feedback of energy use is most efficient when:

- the users voluntarily put up quantitative goals to reduce energy use
- the users fully comprehend the information
- it is frequent, that is recurring frequently and regularly
- the energy cost is making up a significant part of the household budget.

McCalley and Middens (2006) are criticising researchers of feedback intervention studies of energy conservation for neglecting to investigate the underlying relationship between feedback and action. They argue that the experimental designs investigating energy feedback have been “hit-or-miss” designs, leading to highly variable results. They suggest that:

> “Frequent and specific *feedback is a successful means of encouraging energy conservation when users are first encouraged to set a goal.* /.../Feedback serves as the information a user needs to assess where they stand in relation to the desired goal, and thus *energy conservation results only when the user forms (or has formed) a specific goal to save energy which is matched to the energy feedback.* (Pp 134-135, my cursivation).

Or, as put by Locke (1991): feedback in itself *“represents information and unevaluated feedback is effectively neutral”*. In an earlier study carried out by McCalley and Midden (2002), it was shown that social orientation (a personality factor) was found to interact with goal-setting modes. The aim of this study was to explore the roles of goals to save energy through product-integrated feedback, in this case on a washing machine. The conservation goals were set and feedback was given via a simulated washing machine control panel. The results showed that pro-self individuals were saving more energy when allowed to self-set a goal, and pro-social individuals were saving more energy when assigned a goal.

Indirect feedback is not reaching the user instantly. Thus, cognitive connections between behaviour and energy consumption become more obscure. It is probably due to this fact that the savings from indirect feedback are lower than for direct feedback (0-10% and 5-15%, repectively), shown in Darby’s literature study from 2006. It must also be stressed that feedback should not be regarded as a separate modifier or strategy to influence energy savings in households. Instead it is a vital part of most other modifiers, such as information strategies, economic incentives and physical planning (Klintman, 2000).

3.3.3 Monitoring and billing

Monitoring is a necessary activity for electrcity and district heating utilities in order to be able to charge customers individually for their energy consumption and to manage supply and network capacity. Monitoring is also required for creating feedback about energy consumption. For utilities, the data from monitoring can be utilized to develop new tariffs and pricing mechanisms, and for segmentation of customer groups based on data on energy use and load patterns. It can also be used as a basis for how new energy services can be developed and offered to customers, for example energy statistics, informative billing and information provisions on efficiency measures. These energy services can help to improve customer relations or contribute to company profit.

Although there is also a relatively large potential of energy savings from indirect feedback, the presentation of feedback from monitoring is very important. However, there are indications that the presentations in the past have not been very sufficient from a customer point of view:

> “Consumer rationales behind monitoring however are mostly ignored, as most monitoring schemes follow the providers’ logic and language of flows and numbers, instead of being translated into consumers’ needs like comfort, cleanliness and convenience.”(Van Vliet, 2000, p 39).

In the end of the ‘80s and the beginning of the ‘90s, quite a few projects were implemented that aimed to test the effectiveness of informative energy bills on energy savings. In 1996, Nutek[22] made a compilation of the Nordic projects undertaken in those years. Comparison of the outcome of energy savings in the different projects shows a range between 0 and 12%. However, the different settings in the projects make such a comparison less useful.

Different types of feedback information can be included on the energy bills:

- Historical feedback
- Normative feedback
- Advice on energy saving measures.

Wilhite, Høivik and Olsen (1999) report that historical feedback on energy use led to energy savings and positive customer responses in an experiment in Stavanger, Norway. With historical feedback they refer to data that indicate how much energy the customer uses in every billing period of the current and previous years. Based on these results in Stavanger, the Norwegian Water and Power Authority (NVE) introduced new billing guidelines for all Norwegian utilities effective in 1999. The guidelines require billing for actual use at a minimum of 4 times per year, and the incorporation of graphical historical feedback on the electricity bill (Wilhite et al, 1999). These findings also inspired the Swedish Government to legislate monthly billing of household customers for electricity.

Normative feedback provides the household with information on how much energy it uses in comparisons with other similar households. In previous studies, it is shown that normative feedback can act as a motivating factor if the user is discovering that he or she uses more energy than similar households. Appropriate reference groups can be compounded by different factors (Matsson, 2001):

- Street name
- House type
- Number of household members
- Type of heating system
- Living space

[22] Nutek is the Swedish Agency for Economic and Regional Growth.

As mentioned in the introduction, new demands for billing have also been set in the EU directive from 2006 (2006/32/EC), article 13 (See Appendix A). For electricity, natural gas and district heating customers, individual monitoring that accurately reflects the final customer's actual energy use is demanded[23]. Also, frequent billing based on actual consumption is emphasized in this directive and the bills shall provide the customers with a comprehensive account of current energy costs. Moreover, the demands for the information in, or with, the bills from energy distributors, distribution system operators or retail energy sales companies are very substantial. The information shall contain:

- current actual prices and actual consumption of energy;
- comparisons of the final customer's current energy consumption with consumption for the same period in the previous year, preferably in graphic form;
- wherever possible and useful, comparisons with an average normalised or benchmarked user of energy in the same user category;
- contact information for consumers' organisations, energy agencies or similar bodies, including website addresses from which information may be obtained on available energy efficiency improvement measures, comparative end-user profiles and/or objective technical specifications for energy-using equipment.

It is evident that energy bills have been an issue for a long time now on the national level as well as the European level, and that policy has acted on the research findings through new legislation. The new regulations will make the information on energy bills become both more specified and more lucid.

3.3.4 Making energy visible

The installations of new Automatic Meter Reading (AMR) with two-way communication can enable the utilities to develop new energy services. Feedback on energy use can be communicated through other media than energy bills, for example through the Internet. The Swedish utility Skånska Energi was an early adopter of AMR, and this utility started to install their "CustCom-system" already in 1998. In 2001, Peter Matsson and Anna Ketola[24] carried out a field study where they investigated an Internet-based statistical service offered cost-free to 90 customers by this utility. Surveys, interviews and statistical analysis were conducted to register, study and evaluate the customers' use of the service and the possible influence that the service had on electricity consumption. In order to use the statistical service the users had to log in to a homepage using an individual username and password. Consumption data could be demonstrated as bar charts, area charts or line charts with different resolution down to one hour. Latest available data was from the previous day. The web module also enabled export of data to Microsoft Excel if the users wanted to make their own diagrams. Results from the study showed that although 80% of the customers answered that they were interested in getting statistical information about their energy consumption, less than 40% actually used the internet-based statistical service during the four-month test period.

[23] In so far as it is technically possible, financially reasonable and proportionate in relation to the potential energy savings,

[24] Former researchers in the Efficient Energy Use in Buildings Research Group at Lund University

The following four reasons were given by the respondents as to why they had not used the service:

- Did not have any computer or access to the internet
- Did not have the time to test the service
- Forgot about the offer or did not know about the service
- Did not take any interest in the service

No statistical evidence of energy savings due to the use of the statistical service could be shown. One conclusion from the results was that in order to get the customers to use the service, they must first know about it and hence advertising carried out in many different ways becomes very important to raise awareness. Another conclusion was (not surprisingly) that some customers were not familiar with using the internet or computers at all, especially not elderly people. Internet accessibility and computer skills probably have increased in the Swedish population since this study was conducted in 2001, which means that at least some of the obstacles have been removed for the use and accessability of this type of energy service. The statistical service was offered to all customers of the utility in 2002 and is still used today, however follow-up studies of the service have never been realized. The statistical service is reached from the utility homepage, where information about the service and how it works can be found.

When the installations of AMR have been determinated by most of the Swedish utilites, there is a possibility that these kinds of services will be common goods for residential customers in the future. Although is seems that many of the utilities will only collect the hourly data once a week due to the large costs for collecting substantial amounts of data on daily basis. Hence, the feedback information in this case would not be based on data from the previous day, but from up to one week. If the service is charged, the collection costs can be motivated nonetheless, and more frequent data can be available.

However, there is a risk that these services may become obsolete due to the rather cheap energy feedback devices for home use that now are becoming available on the market. Advances in micro-elements and computing have contributed to this development of devices that can accumulate data and show expected monthly utility costs. In an evaluation of energy demand feedback devices by Parker, Hoak & Cummings (2008), the authors showed that devices like this are now available on the market for 140 USD.

Some developments of devices giving inadvertent feedback have been developed to visualize energy use. In Sweden, *the Interactive Institute* (a multidisciplinary, innovation-oriented research institute) has invented an electric radiator consisting of light bulbs. The user can acquire some understanding of the volume of the electricity needed for heating when counting the light bulbs on the radiator. The Interactive Institute has also developed an electric wire that glows: the more energy is used, the brighter the wire glows, thus visualising the electricity use through the wire. A similar concept was invented by Shane Ellis and Terry Brown, in the shape of a power outlet that glow red when electricity is used and glow brighter the more electricity is used[25]. A somewhat more gimmick-like invention is the "the

[25] Source: http://dvice.com/archives/2008/03/power_outlets_g.php, downloaded 14 April, 2008

Consumption Feedback Switch" [26]. This electric switch for lighting emits a delicate sparkle from the switch when you turn it on.

The invisibility of energy makes the product/service hard to advertise or market. Lindstedt and Mårdsjö (2000, in Lindstedt & Mårdjö Blume, 2006) have shown that marketers, in order to visualize energy (electricity), had to contextualize the invisible in their advertisement texts, for example by using metaphors like "green electricity" or by letting fictive electricity consumers represent the different choices valid on the market.

In the Hedebygade Project – a Danish experiment of visualising energy consumption – three different elements were used to visualise energy consumption (Jensen, 2003):

- **Visible meters** were placed in each flat, usually in the hall.
- **Personal diagrams**. Each flat got a quarterly account informing the tenants about water and energy consumption in each flat of the specific house, normally two or three stairways.
- **Eco-accounts** were distributed to each household explaining the level of consumption compared with the other households in the block. An eco-account produces five key figures of consumption (which are measured in quantity per person). The key figures concern heat, electricity and water consumption, as well as estimated waste production and CO_2 emissions. Diagrams showing the consumption of a block as a whole was put up on the notice board of each stairway.

Reductions of heat use and electricity use were shown within the first year to be 9% and 22%, respectively.

The eco-accounts are interesting in the sense that they are not only referring to energy consumption, but also to some extent to the environmental consequences of the energy use. It has been argued above that motivation is vital in order to achieve energy savings from feedback, and the qeustion that has to be raised is then: why do people want to save energy in the first place? In isolation, feedback on energy consumption is not really interesting. People try to save energy in order to save money or to save the environment. Should not these relations be reflected in the feedback?

Enhanced collaboration between customers and utilities might strengthen the relationships between them. This has been seen in the United Kingdom in the example of white certificates that have been used since 2002. The system of white ceritificats implies that the energy utilities get a piece-work contract to conserve energy at customers in some way. In United Kingdom, insulation of houses has been one common activity, and this has strengthened the customer relations in the way that fewer customers have changed their power-trading companies.[27]

[26] Source: http://dvice.com/archives/2008/03/consumption_fee.php, downloaded 14 April, 2008

[27] Source: Swedish Energy Agency: http://www.energimyndigheten.se/sv/Forskning/Manadens-forskare/Lena-undersoker-energipolitikens-styrmedel/, downloaded 4 May, 2008

The interest of intervention studies was larger a decade ago, but interest will probably rise again in the future. However, the research on energy use feedback would benefit from a larger emphasis on *what* it is that motivates people to save energy. Then, the design of the feedback should be developed according to these results and be used together with other modifiers, like for example information on *how* to save.

4 Households as Subjects of Analysis

The studies included in this thesis are looking at customer responses to different proposals from energy utilities. The study subjects in the different studies are hence Swedish households and their providers of electricity and district heating.

This chapter aims to describe some important characteristics of households (with an emphasis on Swedish households). The description is based on theories and research within the research fields of sociology and economy. The chapter also aims to highlight some methodological implications of the use of households as a study subject or unit of analysis.

Households are often chosen as the unit of analysis in various energy studies, sometimes probably without much consideration. There are, however, several factors that make this choice practical. One thing is that households constitute an economic unit with household members sharing the household budget. Another thing has to do with the fact that the dwelling place is shared by the different household members and this means that a lot of the services like electricity, heat, water, domestic hot water, waste disposal and so on are shared in the household. These services are often measured and paid for on a dwelling or household level. Also social and cultural aspects of the household as a nuclear unit in the society (i.e. values shared in families, activities and projects executed and planned within the household) make the household a natural unit for many micro-economic studies and government models, including energy studies.

According to the Free Dictionary[28], the term household refers to the people that live in the same dwelling *and* the belongings to this unit:

> *1.*
>
> *"A domestic unit consisting of the members of a family who live together along with nonrelatives such as servants"*
>
> *"The living spaces and possessions belonging to such a unit".*
>
> *2.*
>
> *"A person or group of people occupying a single dwelling: the rise of nonfamily households.*

[28] http://www.thefreedictionary.com/Household, downloaded 14 February, 2008.

The EIA (Energy Information and Administration – the US department of energy)[29] holds another definition:

> "A family, an individual, or a group of up to nine unrelated persons occupying the same housing unit. 'Occupy' means that the housing unit is the person's usual or permanent place of residence."

The last definition elucidates the concept by adding "usual or permanent place of residence" to the explanation of the term (even if one may question the limitation of household members drawn here).

In the journal *Sociology*, Clair Wallace published an article about *household strategies* and their conceptual relevance and analytical scope in social research. The use of the term strategy when it comes to households has been criticised from the point that this implies agency and active planning (an activity earlier described only in the military or in organisations) rather than structure and that emphasizes informal and domestic work rather than formal. Household strategies have nevertheless been the aim of investigation in many social and economic studies. In this article Wallace discusses the idea of household strategies as a **concept** *"that takes into account the motivations and agency of actors in society"*, as a **method of analysis** *"through looking at the intersections of different economies in household behaviour"* and as a **unit of analysis** *"with a focus on households rather than individuals"*. Furthermore, Wallace states that:

> "...Many researchers find household strategies to be a useful concept in understanding household economic behaviour, because it steers a course between the Scylla of the 'oversocialized' conception of the individual /.../ and the Charybdis of the calculating and resource-optimizing homo economicus which is assumed in many economic models. However, in choosing this course, we would also take into consideration the more sociological variations in the norms and cultures that constrain human behaviour. If studied in this way, the study of household strategies can be a way of understanding the interaction of structure and agency" (Wallace, 2002).

Wallace argues that the importance of the concept of strategy is that is based upon the assumption that one must ask households or individuals themselves what they are doing in order to understand how they make sense of their own environment (ibid). This perspective of household agency shows similarities to the perspectives about consumer roles showed in chapter 3.2.

4.1 Type of household

Type of household depends on the size, the economy, the housing conditions, the gender, age and ethnicity of the individuals, composition of individuals and the socio-economic status of the household.

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[29] www.eia.doe.gov/neic/datadefinitions/sectors25B1.htm, downloaded 14 February, 2008.

In Sweden, almost half of the households are single-households (Statistics Sweden)[30]. Single-households consume more commodities and use more energy per capita than larger households, especially younger males without children.

The electricity use *per capita* is systematically higher in multi-family houses than in detached houses. This is due to the minimal level of standard of a normal home, which means that some electrical equipment and electricity use will be the same whether the household contains one member or more. Since the households systematically are bigger in detached houses than in apartments in multi-family houses, the domestic electricity use is anyhow higher in detached houses (Bladh, 2005).

A higher energy use for showering could be found for households with teenageers, and households with children were shown to have a higher indoor temperature compared to households containing adult couples or singles (Levin Kruse, 1991). The amount of laundry is also typically substantially higher in households with children and teenagers, although there is also shown that younger families have switched to newer white goods (like washing machines) which made the energy use for laundry per person almost the same (Nutek, 1994).

Since most of the study subjects in the studies of this thesis were living in detached houses, the households were more often families with children and older couples where children had moved out, than young single-households.

4.2 Life cycles

The life cycle and the specific life situation for a household affects the possibilities and directions of households. Younger households often have economic limitations. The situation is changing over time with rising salaries that often are connected to family formation and the moving to a new, usually larger dwelling. Moving house seems to create a high level of vitality and several energy-related decisions are made at these occasions. The situation again changes for middle-aged households when children grow up and move out. In the later phases of the household life cycle, smaller living spaces are required and decisions about heating systems are influenced by aspects of comfort and dependability (Isaksson, 2005).

4.3 Everyday life in households

Everyday life in households is, to a great extent, compounded by routinised actions. These actions must be combined in such way that all the actions can be attained within a certain time interval. The rational time use is, in this way, the main objective, thus focusing on the calculation of resources of time, distance and money in order to reach the goal (Wärneryd, Hallin & Hultman, 2002).

Everyday life is taking place on many different arenas where the home is just one. Habits that are taken on in the home usually are brought about outside the home as well. In Ellegård & Wihlborg (2001) the concept of everyday life is discussed as an elusory concept that is difficult to define, because it is a multi-dimensional and complex concept hard to fit into just

[30] Source: SCB: http://www.scb.se/templates/tableOrChart____163554.asp, downloaded, 29 April, 2008.

a single category. In Ellegård and Whilborgs' minds, everyday life includes Monday to Friday as well as Saturday and Sunday, working life as well as home life.

People adjust their daily lives to different restrictions that affect their freedom of action. There are different kinds of restrictions:

- **Restrictions from authorities and means of control.** These restrictions are created by organisations whose legitimacy and authority are prescribed by laws and regulations. Examples of this can be schooling, timetables for transport, access to childcare system and work hours.
- **Restrictions through interaction between members in the household or immediate family.** The restrictions are built on promises and obligations that are maintained and constantly reconsidered in the daily life.
- **Restrictions due to deficient capacity**, for example tangible assets, knowledge, physical, economic and technical resources.

Flows of *activities* occur in our daily lives either by choice or by the influence of different restrictions. Certain activities are carried out almost without any consideration. Many activities are included in different *projects* and others can be included in several projects at the same time. For example, the activity of "riding the bike to work" can be part of the project of "transporting yourself to work", the project "to maintain a healthy body" and/or the project of "saving the environment." Projects and activities are interrupted by recurring physiological basic needs (i.e. to sleep, to eat and to care for personal hygiene). These activities recur in a rhythm that makes up the basic structure of every day life (Ellegård, in Ellegård & Wihlborg, 2001).

The organisation of everyday life and the restrictions influencing it determine the time use for different members in the household. This time use is highly related to peak load patterns in the households, and hence time use and organisation of everyday life becomes an important, yet unexplored research area.

4.4 Use of time

There is a widespread preoccupation with the speeding up of everyday life in modern societies (Wajcman, 2008). Many factors are contributing to the pace of life speeding up. Wajcman suggests that researchers should look at households instead of individuals since the discussion about avarage hours of work masks a dramatic distribution of paid work between the sexes. Merging time use for paid and unpaid work together, there is very little difference in the time that men and women spend at work according to the Brittish researchers Bittman & Wajcman (2000). The same relation also exists in Swedish households according to time use studies conducted by Statistics Sweden (SCB, 2002). Wajcman suggests that the experience of rush is not only depending on duration or volume of time, but also with the "quality of time", which is affected by the social tendency to perform more tasks at the same time within a given period, or multi-tasking. The lack of time often leads to higher energy consumption (Shove, 2003). For example, people might buy ready-made frozen food that they heat up in the microwave oven, instead of cooking themselves.

Due to the liberalisation of different markets, individuals and households today have to make a lot of decisions in order to choose between different providers or companies. In Sweden, new markets for electricity, telephone, taxi, aviation and so on, have opened up in the last decade or so. In order to feel updated and informed about the different options, households would have to spend quite some time on finding and comparing information.

4.5 Gender and generation

Relatively few energy studies are looking at gender differences (Carlsson-Kanyama & Lindén, 2002), although in most questionnaire studies and interview studies, gender is reported as a demographic variable and hence some results can be found that illustrate gender differences (Aune, 1998).

The division of responsibilities for different matters in households are traditionally quite gender-specific, where:

> "...gender specialisation in economic activities within family is widespread and has some common elements, in particular primary female responsibility for the care of children. That there is a link between a mother's commitment to her children and wholesale female disadvangate has been asserted by many family and gender analysts" (Lundberg, 2005, p.1).

Care for children largely influences the way households construct their lives in terms of carrier planning and responsibility for domestic work. In SCB's study from 1990/91 and 2000/01 a change was reported in how much time was spent on housework, comparing the "generalised" days of men and women in Sweden. The number of productive hours has decreased from 1990 as a result of the fact that both unpaid work and paid work have decreased, counted in time. Men and women have also become more alike in the composition of paid and unpaid work. But it is doubtful whether this change should be seen as an expression of gender-equality since men were not taking over more of the domestic work from women, only showing that less total time in the households were spent on domstic work. Nordell (2003) though, stresses the possibility that for women, putting in less effort in domestic unpayed work can be a way to manifest gender equality (Nordell, 2003).

Empirical results form Nordells research show that the life in Swedish houesholds still, to a certain degree, is organised in a traditional way. Women spend considerably more time at home and less time at paid work than men. Women spend more time at recurrent domestic tasks inside the house; wheras men spend more time on infrequent activities preferentially outside the house. Gender differences are specifically higher in the oldest ages, where women are carrying out almost all the domestic work; wheras men are mending the car or work in the garden. There is a quite large difference also in the age group of 10-15 year olds. Girls in this age group are spending considerably more time on domestic tasks like cooking, baking or cleaning, than boys. Considering the fact that behaviour and habits presumably are formed in the early days and have more penetrating power than values and attitudes, this is somewhat remarkable (ibid).

Cleaning, doing laundry, cooking or helping others with personal hygiene are typical activities that occupy a lot of the timeespecially for women in the age groups 26-45 years and 46-64 years, but it is also evident that older women (pensioners) spend more time on cooking and baking, than other women (and men). It is also evident that men are more involved with activities of doing laundry, ironing and cooking in the age group 26-45 years, which is typically the time were chidren are small and the organisation of the domestic tasks must be shared, especially in families with two fulltime careers. Time for watching TV/video or using a computer is considerably lower in these age groups compared to other age groups, but men are spending more time on these activities compared to women in all age groups – except for 19-25 year old women that watch TV/video somewhat more than men their age (ibid).

Linking these results to energy use in households, efforts to save energy in households would probably affect women more than men, since they spend more time at home doing domestic work. There is a clear connection between energy use and domestic work, since a lot of the work is carried out with help of electrical appliances. Whose responsibility it is to carry out certain task has an implication of who is using the energy and when the energy is used. If, for example only the woman in a household takes responsibility for the laundry, laundry will occur when she has the time to do it.

The division of labour in the home could also be seen in the light of the shaping of a self-identity, since domestic tasks may provide self-esteem or the feeling of self-fulfilment by action (Kaufman 1997, in Bartiaux, 2003).

Some gender differences may also be found in how men and women view the electric appliances. It is argued that men attribute an instrumental value of these appliances which represent their social achievement, whereas women more often insists on the object's symbolic value that represent affective ties (Dittmar, 1989).

Gender differences also occur in level of thermal comfort. Thermal comfort is defined in ASHRAE Standard 55 (or ISO 7730) as:

> *"that condition of mind which expresses satisfaction with the thermal environment."*

Thermal comfort includes environmental factors (air temperature, radient temperature, air velocity and humidity) and personal factors (clothing insulation and metabolic heat)[31]. Since thermal comfort is a personal experience of the level of comfort, there is no perfect thermal indoor climate that fits all people.

Karjalainen (2007) showed that females prefer higher room temperatures than males and feel both uncomfortably cold and hot more often than males. This Finnish study also showed that although females were more critical of their thermal environment, males use thermostates in households more often than females, something that can be compared with Dittmars view above.

A Chinese study (Lan, et al, 2008) showed that females were more sensitive to temperature and less sensitive to humidity than males. The comfortable operative temperature was generally higher for females than for males (26.3ºC compared to 25.3ºC).

[31] Source: http://www.hse.gov.uk/temperature/thermal/factors.htm, downloaded, 29 April, 2008.

The findings on gender differences in thermal comfort thus tell us that women are more sensitive for low and high indoor temperatures, which is something to take into account in saving measures or load management of households' heating or cooling systems. Changes in metabolism in older people are, by the same token, important to keep in mind.

A study by Lindén (1994) showed that women are more environmental-conscious and are generally more concerned about environmental problems than men. In a study of energy behaviour of 800 households in Sweden, Olsson (1995) showed that women performed more energy-conserving behaviour than men, for example switched off the lights when leaving a room, turned down space heating during the night and avoided doing laundry with half-filled washing machines. This gender difference was however not supported in a study by Carlsson-Kanyama in 2001 on 600 households in Stockholm.

Values, attitudes and behaviour are appropriated in childhood or adolescence and these act as reference points and norms for attitudes and behaviours later in life (Mannheim, 1952, in Carlsson-Kanyama et al, 2003). In Lindéns study about how pensioners make plans for living, she found that for every generation of people born in the 1930s, 1940s and 1950s, the dwelling contained one more room regardless if they lived in detached houses or apartments (Lindén, 1994). Older generations are mainly more successful in carrying out colloquial environmental behaviours than younger generations (Lindén, 2001), although younger generations often do have better theoretical environmental knowledge (Carlsson-Kanyama, et al, 2003).

The differences between women and men drag up the subject if it would not be better to focus on female experiences in some research questions and on male experiences in others. The problem is that the households are treated as a unit of analysis in research. Methodologically, it would be possible to, for example, make more than one interview in households with more than one individual. The benefits from taking this concern must nevertheless be put in relation to the additional costs in time, money and other resources that would be required, and the aim of the study must determine whether this approach would be worthwhile or not. This concern was not taken in the interviews in my studies, however, in the energy diary study in Paper 5, household members were treated individually.

4.6 Decision-making in households

Not going very deeply into theories in decision-making in households, a few points will nevertheless be mentioned. Joint-purchase decisions are often far more complex than individual consumer choices. The needs and interests of several participants have to be considered at the same time (Wilkie, et al, 1992).

Much research on household decision-making focuses on the decision-making process of husbands and wives (as a concentration on the nuclear-family still exists in many research areas examining households). According to Wilkie with colleagues, the research on decision-making made by husbands and wives has shown that the particular forms of influence from the different parties in the couple, depends on a number of factors including:

- The product
- The stage of the decision process
- A couple's sex-role orientation

- The intensity of each individual's preferences
- A couple's consideration of equity or fairness issues within the context of their relationship

There is some evidence that the technical sphere of artifacts might be a male-dominated area (see chapter 4.1.3), however large decisions are often made jointly and information collection, making contact with craftsmen and reading manuals can either be a shared or an assigned zone of responsibility, implicitly or explicitly agreed on.

4.7 Households as a unit of analysis - methodological implications

When households are used as a unit in research, there is a risk of loosing accuracy of data. Instead of using continuous variables of, for example age, age groups are developed, which implies a nominal or perhaps an ordinal scale. It can also be difficult to categorize households in terms of, for example, education level or type of profession. Among the household members, whose education level and whose profession should be the basis of the categorization? In statistical studies, you do not want to end up with too many categories because small numbers in one category might decrease the power in various statistical tests. Is it fair to categorize the households by the person with highest level of education in the household for example? These kinds of methodological questions must be viewed upon from the perspective of the research question. In the survey in Paper 1, we had to handle these kinds of questions, where we choose to categorise the households after the highest level of age and education.

In single households the individual and the household are the same. But in households that consist of more than one person, it is common that only one representative of the household answers the questions in questionnaires or interviews, probably the one most conversant to the research subject. Naturally, there is a risk of loosing valuable perspectives and information from other household members here.

The gender differences brought up in chapter 4.1.5 were considered or at least noticed in some of the studies that are included in this thesis. In the study about the customers' view of choosing heating system, Paper VII, the households were given the oppotunity to decide by themselves who would participate in the interview. This possibility was given to enhance the households' willingness to participate in the interviews. The consequence of this was that men were over-represented in the interviews, especially in elderly households. Maybe the heating system is still viewed as a male sphere in these households? Among younger couples, both the man and the woman participated, and both were active during the interview. Hence, a gender-generation pattern could be traced here.

The methodological approaches of the different studies are described more thoroughly in the next chapter, see chapter 5.

5 Methods used in studies

The research problem should determine the choice of methods – not the researcher's knowledge or experiences of different research methods. Djurfeldt and colleagues (2003) advocate methods pluralism instead of fundamentalism amongst social scientists. The methods used in this thesis are chosen, as far as possible, from the above-mentioned standpoint. Therefore, many different quantitative and qualitative methods have been used in the studies, sometimes in combination or with a modification from other research studies or researchers:

- Survey questionnaires
- Interviews
- Highly resolved energy measurements
- Energy diaries
- Load management experiment
- Comfort sheets
- Data collection from municipal records
- Follow-up meetings
- Yearly energy use

Sometimes the application of several methods used to investigate the same research problem – often called triangulation – may be very helpful for "cross-examining" the problem and validating the results. In the following subchapters the methods used in all the studies of this thesis are described.

5.1 Investigating customer preferences of electricity bills

In the beginning of this millennium, several studies were carried out in Norway, Sweden and the USA, that showed that *information about electricity use on electricity bills* could have some effect on the electricity use in households. The Swedish Energy Agency commissioned an inquiry about whether the period of electricity metering for Swedish households should be altered, and if billing based on pre-estimated values should be removed or not. The research group of Energy Efficient Buildings at the Faculty of Engineering, Lund University, carried out this study in the Spring of 2002. The Commission was motivated by a general consumer interest and a presumed possibility that this could lead to energy conservation as described in Chapter 3.3.3.

The study compared households within three local electricity networks owned by Smedjebacken Energi AB, Lunds Energi AB and Skånska Energi AB, where Smedjebacken Energi AB had a billing system based on monthly metering and on actual electricity use. The other two utilities, which did not have billing based on actual use, served as control groups for comparing statistics, but as part of the investigated population in descriptive statistics.

A survey questionnaire was developed with questions concerning the house, the household energy use, attitudes toward the electricity bills, energy statements and a few demographic facts about the household members. The questionnaire was tested in a small pilot study before it was sent out to 3,000 randomly sampled household customers belonging to the three Swedish utilities. The response rate was just about 35% in all three groups (32,4%, 34,9% and 37,0% respectively). A statistical evaluation on the power of the data on electricity use showed that 220-340 answers were needed to be able to discover significant differences of 1 to 2%, with a probability of 95% ($\alpha = 0,05$). This responded to an answering frequency of 32%, which hence was achieved in the study (Blom, 1998).

The study resulted in a Swedish report. The results of the study showed that the hypothesis that billing based on actual use leads to lower electricity consumption neither could be verified nor falsified based on the findings of the study, where a longitudinal experimental design would have suited the purpose better. Nevertheless, the study did give a good understanding of the households' preferences and attitudes towards their electricity bills, which led the research group to write Paper I, included in this thesis.

5.2 Load-control experiment and study of household load patterns

5.2.1 Selection of ten households

In the studies of load control (Paper IV) and investigation of household load patterns (Paper V), ten household customers from the Swedish utility Skånska Energi AB were selected. The selection was based on earlier studies carried out by the research group, where the utilities' technical possibilities of the new CustComsystem were studied by North (2001). In North study, nine households were selected for continuing studies, but only seven of these are included in the load control and energy diary study, and hence three new households were selected.

The selection of households was mainly based on technical premises from the households' heating systems, due to the technical research questions stated by my fellow research colleagues and the above-mentioned study by North. For the research questions in this study other principles for selection could have been beneficial to get a larger variation of the demographic variables of the households. There is, for example, an over-representation of middle-aged to older households (50-75 years). Only two of the households have children in the age of 18 or below. The number of household members varies from 1-4 members, but most of the households consist of couples where the children already have moved out. For more information on households and buildings, see Appendix B. The demographic homogeneity of households can perhaps be explained by the inclination of these households to participate in the studies given in proposals in earlier studies of the research group.

5.2.2 Schedule over research activities in the ten households

The ten households participated in several activities in the load control experiment and the energy diary study. To get an idea of the research design, see the chronological schedule in Table 3:

Table 3: Schedule of research activities in the ten households.

Schedule of research activities in the households

February - March 2003
- Installation of two extra electricity meters for heat and hot water
- Start of collection of metering of electricity use (total, heat and hot water
- Technical inventory of characteristics of house, heat- and hot water systems

December 2003:
- Information letter was sent to the households
- Information meeting was carried out with each household separately
- Dispatch of energy diaries

January 2004:
- Electricity meters were adjusted to measure 5 minutes interval
- Households members kept energy diaries for four days in January (Thursday-Sunday, Friday-Monday or Saturday-Tuesday)
- Follow up meetings where the researcher and the household compared diary notes with household load curves with 5 minutes resolution.

February 2004:
- Temperature loggers was rigged to measure indoor temperature (15 minutes resolution)
- Notebooks for noting heat- and domestic hot water comfort where distributed to the households
- Period for load management 16 February – 7 March

March 2004:
- Interview with households were carried out
- Temperature loggers were collected

5.2.3 Developing a method for studying load patterns in households

To investigate the load patterns in the ten households and what appliances and activities that contributed to the peak-load of each household, a combination of different methods was used: energy diaries, frequent electricity meterering for three loads and follow-up meetings with each of the households directly after the household had finished their diary period. In Table 4, the type of information gathered from the different activities is showed:

Table 4: Type of information gathered through the three different methods used.

Energy monitoring	Diary	Follow-up meeting
Patterns of electricity use	Household activities related to energy use	Control of consistency between diary notes and electricity metering
The magnitude of the different loads (intrinsically and in relation to each other)	Appliances used	Information of timing of appliances
Time of peak loads	Time of activities	To track electricity use on the load curves that was not explained in diary notes.

By combining the three sets of data, household load patterns could be comprehended in terms of when electricity peaks occur, what activities are involved and what appliances are contributing to the load peaks.

In other research studies, diaries have been used to decide where and when events and processes have occurred. The interaction between time and space has been a central starting-point. Large time-use studies have been carried out in Norway, Finland and Sweden during the 70s, 80s and 90s. In these studies the activities and time use of the population has been mapped out. Other examples where diaries have been used to collect data is in research that aims to study mobility of people, in studies of how people use media and investigations of certain patient groups. For the last sector of application, the diaries have rather been of an introspective character, where the writer of the diary not only notes events, but also the feelings attached to the events.

To be able to capture habits and routines in everyday life, a real time perspective must be used (Rahm & Wihlborg, 2003). In Figure 3, differences between a real-time perspective and a time-added perspective are shown. In a time-added perspective, information about how many times a certain activity is carried out gets lost, as does the context where the activities are carried out.

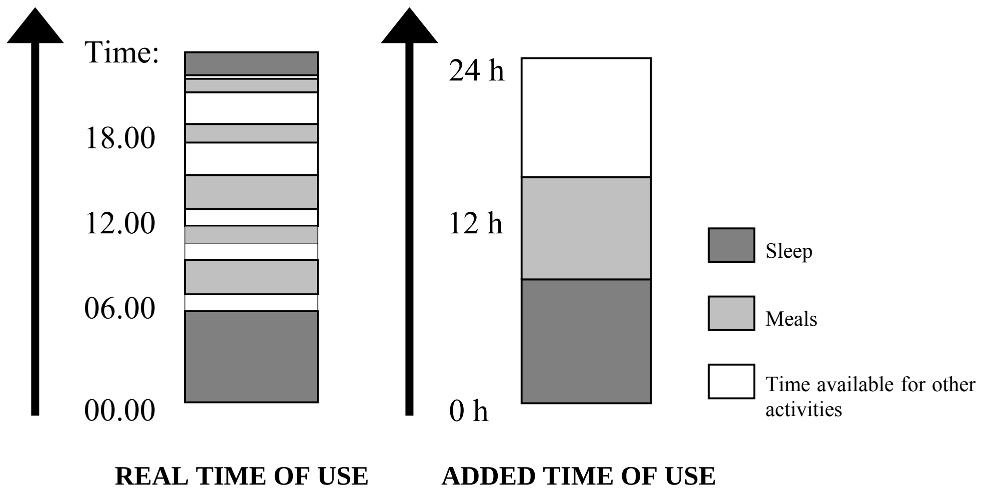

Figure 3: Real time and added time of use (Source: Ellegård, 1990).

To study the household "load behaviour", a real time perspective must be used. For this reason, an energy diary was developed in this study. To use an energy diary as a tool for capturing activities and appliances that contributes to peak is quite similar to the use in time-use studies. The difference is that the energy diary only focuses on those activities where energy is used.

At Linköping University in Sweden, diaries have frequently been used as a means to gather information about people's habits and their time use[32]. Also studies of water use have been

[32] Tema Teknik och Social förändring

carried out in Linköping. This research field has many affinities to energy use because of the socio-material components influencing habits and routines, and that the use of domestic hot water also is included in water use as well as in energy use of a household. Contacts with the research group in Linköping gave insight into what methods and diary sheets had been used in their research[33]. The diary sheet used in this study was to a great part influenced by the diary sheets developed at Linköping University.

The diary used in this study has six columns: one column for notes of time, two columns for activities (if more than one activity is carried out simultaneously), one column for appliances used, one column for where in the house the activity is taking place, and finally one column for comments.

Notes of time

In many time use studies time periods are predetermined, usually 10 to 15 minutes. Ellegård (1993) stresses some problems that can occur with fixed time periods. For example, if some 10 minute square is not filled out, there is no way to decide what activity has been carried out in this field and whether the empty space is representing 2 or 18 minutes. Another problem is that diary keepers tend to underestimate short hold activities.

Ellegård (ibid) distinguish between quotidian and analytical time perception. In the prosaic time perception, time and activity are so closely related that they are experienced as a unity, whereas in the analytical time perception, time is regarded as continuous. When developing a method to capture habits and routines, the quotidian time perception becomes more relevant. If people have a tendency to perceive time as subordinated to activities, maybe the diary sheet should be designed in a way that it becomes natural to first note the time and then note the activity. In the design of the diary used in this study, the time periods are not fixed and household members must note the time for the activities themselves.

Another methodological problem with diaries is how to know when an activity ends. This could eventually be solved if the diary keepers where asked to also note the end-time for the activities. In this study, the diary notes were going to be compared with the household load curves and the load curves hereby can be used as a key for when activities have ended. Because of this, the energy keepers where not asked to note the end time for activities.

An alternative way to gather data about energy-related activates in the household would have been to derive from a list of the electric appliances in the household where the persons could cross time of use for specific appliances. But from the argumentation that energy use is more connected to a social practice rather than to the appliance itself, it would be easier for the user to remember the activities rather than the appliance used. The context in which the appliance was used would also be lost. It would also be problematic to list all the appliances in the household as possibly could be used. The finesse with the diary sheet used here is the simplicity: to simply note what you are doing, the time for it and the appliance used, you will not have to search in a matrix where to write.

[33] Personal contact per telephone and e-mail with Elin Wihlborg

Type of data

The electricity use in the ten households was measured with three electricity meters which measured electricity use for space heating, domestic hot water and total use. The electricity use noted in the energy diaries typically referred to electricity use for activities and hence, the consumption that does not relate to activities is not noted, e.g. electricity use for refrigerators and freezers, stand-by power and time-set appliances such as certain lights or additional electric heaters. But even if this kind of electricity use was not noted in the diaries, this is nevertheless showed as a kind of base-load in the load curves of the household.

Heat-load depends on the climate (wind, temperature and solar radiance), the thermal characteristics of the building and the indoor temperature level. Only a small part of the heat load is connected to activities in the household, for example airing, manual control of thermostats, and indirectly by the use of complementary heating such as the use of fireplaces. There is some evidence of the use of fireplaces in the diary notes, and in some cases the indoor temperature level has been noted, but otherwise this is not investigated through the diary method. The electricity use for heating purposes is on the other hand showed on the load curves for space heating.

Quality of data

As is the case in all qualitative methods, the quality of the acquired data depends on the test subjects' willingness and ability to cooperate. The quality of the data from the diaries depends on how thoroughly the test persons have been when noting the time and the activities. Some persons note activities continuously and some recall the activities at the end of the day and then reconstruct the information and write it in the diary (Ellegård & Wihlborg, 2001). These kinds of differences can influence the quality of the data, but this is out of the control of the researcher and one must just accept the conditions. A continuous noting of activities contributes in that the test person does not reflect so much about how many times a certain activity is carried out, and Wihlborg (2003) suggests that this probably makes the data more veracious. In this study, the parallel electricity measurements have worked as a control for the qualitative data.

Diary period

The household were asked to keep diary about energy use for four sequential days including two weekdays and a weekend (Thursday to Sunday, Friday to Monday, or Saturday to Tuesday). Four days is a fairly limited period, which means that the result from this study should be seen as a sample from the everyday life of the ten households. The length of the diary period must be connected to the effort of the activity and how long the test persons can endure the procedure. If a longer period would have been chosen, there was a risk that the quality of data would decrease due to the fact that the participants no longer would give the task the same attention. Besides this, it can be important to bear in mind that the energy diary is only one of the activities that these households are participating in and that require cooperation from the participants. A very long diary period might have compromised the willingness to participate in the rest of the planned research activities.

Because four days is a fairly short period, it is possible that the period is not an ”average” period for the household. This was however not a methodological problem in this kind of study because the purpose was not to define an ordinary week for the household, and because peak load problems usually appear in more extreme situations. Since February (together with

January) is usually the coldest month of the year in Sweden, this period was particularly interesting to follow because peak-load problems most often occur in the coldest periods in Sweden due to a large share of electric space heating.

Electricity measurements

Two extra meters were installed in each household. This made it possible to follow the electricity use divided in heat, hot water and total electricity use. In subtracting the electricity use for heat and hot water, domestic electricity could be obtained.

During the diary period the meters were adjusted to measure in five-minute intervals (instead of the usual 1 hour).

Follow-up meetings

A follow-up meeting was carried out with all households separately directly after that diary period was ended. The aim of this meeting was to go through the notes in the energy diaries, and together with the household members determine activities and appliances on the time scale of the load curves for each household.

The meeting also worked as a control to see if the diary notes corresponded to the load curves. When some electricity use could not be explained by the notes, this meeting enabled the researcher to pose questions to the participants. The use of time-set extra electric heaters, floor heating, engine-warmers, etc., were made clear at these occasions.

The question of whether the participants believed that the keeping of energy diaries had some effect of their energy use was put to the participants. Some individuals reported that they, rather than lie in the diaries, avoided some small activities such as lighting a room when fetching something, because they thought they did not bother noting it. Larger activities, such as taking a shower, work or play on the computer, cooking, laundry and the like was carried out nevertheless according to the participants.

5.2.4 Load control experiment

The data collected in the connection to the load control experiment was the following:

- Indoor temperature was logged every 15 minutes for the load control period of three weeks.
- Measurement data was measured per hour divided on the loads for heat, hot water and total.
- Interviews were carried out after the experiment. The interviews were recorded and fully transcribed before analysis.
- Comfort sheets where distributed where the participants could note comments on heating and hot water comfort during the test period. Also the time where the house was empty was noted.

Table 5 shows the type of information gathered though the different methods.

Table 5: Type of information gathered through different methods.

Electricity measurements	**Measurements of indoor temperature**	**Comfort sheets**	**Semi structured interviews**
The households electricity use	Normal indoor temperature of the household: Level an variation	Daily comments on experiences of heat- and hot water comfort during the control period.	The participants' experiences were discussed in the interviews. The discussions were based on the information from comfort sheet and indoor temperature data.
Magnitude and variation of load	Temperature fluctuations due to load control	Indications if the households noticed the load controls	The participants attitudes to energy or load conservation
Potential for load control		Shows if the household members have been away during load controls.	The participants' views of direct load management or indirect load management through price mechanisms.
Recovering load.			

Design of the load control experiment

The aim of the load control experiment was to technically evaluate what happens with the heat and hot water load before and after the control period, what consequences the load management had for indoor temperature level *and* to give an opportunity to evaluate the heat- and hot water comfort in the households. Because of this there were several factors to consider in the research design for the experiment:

- **Experiment period:** When and how long should the load control period be?
- **Control periods:** lengths of load controls and repetition?
- **Time of the day:** What time of the day was most suitable to shut down heating and electric water heaters?

Household comfort, the needs of the utility and outdoor temperature were taken under consideration when planning for the factors described above. Table 6 shows the different prerequisites that influenced the experiment design.

Table 6: Prerequisites that have influenced the experiment design.

	The household	**The utility**
Experiment period	Household members should not be out of town. To provide enough time for evaluation of heat and hot water comfort.	Peak load problems usually occur when the weather is cold, and at holidays in wintertime. The load control requires resources form the utility.
Control periods	Demands for indoor temperature levels and levels of hot water access.	Needs for load control. Long control periods give rise to higher recover load.
Timing	If household member should be able to notice differences in comfort the control periods must occur when there is a great chance that household members are at home.	Weekdays, the coincidence load in the grid shows morning peaks and evening peaks, and at weekends peaks occur in the afternoon.
Outdoor temperature	The colder the outdoor temperature is, the faster the indoor temperature level goes down at shutdowns.	At colder weather, the demand for load management is bigger.

The experiment period was determined to the 16 February to 7 March, because February, together with January, is usually the coldest month in Sweden.

Load control periods for heating were set to 1-4 hours. Earlier load control experiments had shown reasonable decreases in temperature levels for the households also in rather cold weather conditions. Because we also wanted to test the limits for what will be experienced as uncomfortable, 4-hour control periods were tested at some occasions. Control periods of electric water heaters were varied between 1-4 hours, with an exception of one control period of 16 hours to test the sensitivity of hot water comfort in the households.

The experiment was designed as a blind test. The households were told that the utility could turn off the heating or the water heater at different times during the experiment period of three weeks, but they were not told when and how long the different control periods would be. The reason to use a blind test was to find out if the households really noticed the control periods if they did not now about them.

Comfort notes

The households were given comfort sheets to note daily experiences of heat and hot water comfort during the experiment period. The households were also asked to note the times were they were not at home.

Indoor temperature measurements

Temperature loggers were mounted in each household on an inner wall, 1.30 meters over the floor. The loggers collected indoor temperature every 15 minutes for the experiment period. Accuracy of measurement was ±1,0ºC and the values were rounded to 0,5ºC. Only one logger per house were used, and thereby different temperature levels in different rooms have not been measured. Differences in air temperature and radiation temperature have not been considered, that is the operative temperature level. To be able to measure thermal comfort these factors would have had to be measured more thoroughly, and in the incumbent design the measurements of indoor temperature act as a control measurement towards the experiences of comfort by the households.

Methodological approach of interviews

Semi-structured interviews were performed with the household members to investigate household experiences of the load control experiment. Moreover, the interviews were aimed to grasp the attitudes of the household members towards direct load management in the form that was tested in the experiment, and the attitudes towards pricing mechanisms that were described for the households during the interview.

In semi-structured interviews, the respondents are given the possibility to express themselves freely within a certain topic decided by the researcher. The respondent develops his or her thoughts in the fields that the interviewer finds meaningful. The interviews then usually become somewhat different from each other. This is usually beneficial for the understanding of the phenomena (Lantz, 1993).

Implementation

All interviews were carried out in the households' homes. In most of the interviews all household members participated - the couples, but not the children. This means that gender specific factors often were included in the interviews through the representation of both female and male responses. In households where not all members participated, the interviewed members had to speak for those who were not present. The interviews lasted between 45-90 minutes. They were recorded and later transcribed in full length.

One of the aims of the interviews was to examine the thoughts and attitudes to load tariffs in electricity bills. One methodological insight from this approach is the fact that just by talking about tariffs, the households would not have the full understanding of how these would be experienced in real life. In the interpretation of the results it must then be taken into consideration that the households may not fully understand the phenomenon and that they may change their views should they later experience the tariffs in real life.

For the experiment of direct load management, the households have experienced the phenomenon in real life, but they may also have been influenced by the experimental setting (as compared with the Hawthorne effect)[34].

5.3 Case study with load demand tariff

Sollentuna Energi AB was one of the first utilities in Sweden to install AMR enabling 1-hour measurements on electrcity use for household customers. In order to deal with some consequences from peak-loads, they utility incorporated a load component into its grid tariff. The main objective of the load component in the tariff was to make the customers more conscious of load capacity problems. The long-term aim was to reduce the load demand in the whole service area in order to decrease the level of contracted load (or not to exceed this level which would lead to high penalties) or to avoid expensive grid-enforcements.

[34] See for example: www.psy.gla.ac.uk/~steve/hawth.html

Paper II describes a small case study where the aim was to investigate the impact of the Sollentuna tariff on the utility on different types of residential customers by making comparisons with the previous tariff.

A small customer analysis was carried out with fifteen households grouped into three different categories: flats, villas and semi-detached houses. The customers where randomly chosen by Sollentuna Energy AB. The impact of the new load tariff was investigated through:

- The change in costs for electricty for each customer was calculated by comparing the ordinary tariff from 2000 with the new load tariff from 2001.
- Changes in consumption patterns was analysed through the use of the monthly Load Factor and the ten highest values of load demand each month in 2000 compared to 2001.
- A relative load factor change was calculated: $(LF_{m2001}-LF_{m2000})/LF_{m2000}*100$.

One objection to the analysis is that the analysis did not consider climatic changes between the years of 2000 and 2001. For energy use, there are established methods to include the impact of climate differences by the use of degree-days, but this is not the case for load and hence, this was not made in the study.

Even for electricity use (as apart from load), there are some methodological implications when trying to adjust for climatic differences. This is because of the fact that not all electricity loads in housholds correlate to outdoor temperature; mainly just the load for heating (or cooling) and to a small extent for hot water use (Johansson, 2003). Therefore, the electricity use for heating or cooling must first be estimated or measured.

The possibility to generalize from this study with just a few samples is fairly limited. The results and conclusions could, however give rise to new research ideas and metholological considerations in future studies.

5.4 Investigating expansion strategies of district heating in detached house areas

The study in Paper III was based on a questionnaire study in which the data was used as a statistical base for comparisons between Swedish district heating companies and as information for describing the companies. There were also examples of open questions that gave some qualitative answers to the research questions put in the study. Following topics were included in the questionnaire:

- Background facts about the district heating utilities
- Implemented expansions in low heat density areas
- The companies information about potential customers
- Sales activities

In order to deepen the knowledge in the study's main objective; to survey what kind of sales strategies that Swedish district heating companies use in detached house areas, telephone interviews were also carried out with 17 of the informants answering the questionnaire. In these interviews interesting themes from the answers in the questionnaires were followed up.

The Swedish District Heating Association[35] (SDHA) is the trade organisation of Swedish district heating companies, and has, according to SDHA,[36] 158 members. The members of the organisation correspond to about 99% of the produced amount of heat for district heating in Sweden (Swedish Energy Agency, 2002). The members of SHDA are therefore considered as the target group for this study.

In the middle of June 2003, a first dispatch of the questionnaire was sent out to the members of SDHA. Some district heating companies had the same address, and thereby only 156 companies received the questionnaire. The survey was sent to the managing directors or the marketing directors of the companies. Only 20 answers came in, but after a reminder in September 2003, a total of 51 answers were received. Between SDHA's members several take-overs were going on and some companies choose not to answer the questionnaire with reference to that the parent company would doing it instead. A few companies were shown to be merely heat producers that were not responsible for grid expansions. These companies were removed from the original population, leaving about 150 companies as the target population. The answering frequency would thereby be about 30%.

A rate of answers of 30% can seem low, but this is typically normal or even a high rate for the SDHA members according to contact persons of the SDHA[37]. Nevertheless a low rate of answers may distort the results of the study and perhaps the biggest threat lies in an over-representation of companies with a very positive attitude to expansions, because these could then be more involved and interested in the issue than other companies. As a means for controlling the representation of the companies participating in the study, these companies were compared with existing statistics of all SDHA members. This analysis showed no large discrepancies from the sample population in terms of ownership structure, annual heat sales, share of heat sold to detached houses and fuel mix.

In the analysis of the data and material, the quantitative data has been elaborated and presented as descriptive statistics in frequencies, mean values and dispersion, or in those cases were comparative analyses have been carried out between groups or variables the differences have been tested with significant tests such as Student's T-test, variance analysis (ANOVA), or with a χ^2-test if the data has been at a nominal-scale level. Qualitative data in terms of open answers in the questionnaire and from telephone interviews have been structured and reshaped to create new constructs, for example sales strategies.

[35] Svensk Fjärrvärme

[36] Homepage of SDHA: http://www.fjarrvarme.org, downloaded 2004-04-15

[37] Personal contact with Anders Tvärne, 2004-04-23.

5.5 Choosing district heating – a customer interview study

The purpose of the study described in Paper VII was to study how the households in an area of the city of Växjö acted on a specific offer from the local district heating company Växjö Energi AB (VEAB), in order to understand the background to the households' responses to the offer and what experiences these households have of district heating and the marketing strategy that converting process that VEAB used. The households, which all lived in houses with direct resistive electric heating, had been offered to connect to the district-heating grid in 2001/2002. The conversion included an installation of a waterborne internal heating system, the connection to the district heating grid and the installation of a district-heating substation.

VEAB naturally had an interest in knowing how the households in the area experienced their sales process. An evaluation of the process based on customer experiences could help the company to develop their marketing strategies and to find faults and potentials in the marketing of district heating to customers in detached houses. For other district heating companies it can be interesting to learn about VEAB's marketing process for similar reasons. Other companies must then consider the different prerequisites for different district heating companies and that customer attitudes can differ due to differences in pricing, reputation, experiences and relations to the local district heating company.

To meet the purpose of this study, a qualitative approach has been taken on with semi-structured interviews with a sample of the household in the converted area of Sandsbro, Växjö. As background information about the households living in this area, data was collected from the municipal directory and VEAB's customer file about the persons living in the households, age of household members, year of moving in, which of the households where district heating customers, the yearly electricity use from 2001, and energy use from district heating in 2002. The information was used to make the sample of the 111 households living in the conversion area, and as a statistic base for some quantitative analysis comparing households that accepted the offer of district heating on some variables with households that turned the offer down.

5.5.1 Selection of households for interviews

The share of households that accepted the offer of district heating was 87 of the 111 households, while 24 households chose not to adopt district heating. A special interest was taken to understand why some of the households had turned down the offer, and hence a methodological consideration was made to interview a percentally higher share of households that did not adopt district heating and 10 households (41% of the households that turned down the offer) were selected, and additionally 13 households (15% of the households that accepted) that chose to convert to district heating were selected for interviews.

The selection of the 23 households was based on household type, years living in the house and age of the household members. To include all sorts of households was a methodological consideration of this study, because this could help covering different aspects of household life cycles and living conditions. When a buying decision is made in a household, different members in the household act in different roles and therefore, the constitution of the household can influence the decisions. The selection of households included single households, families with small children, families with teenagers, families with adult children still living with parents, and older and younger couples without children.

One household was selected because their house had been used for demonstration purposes for the installation of a new water-borne heating system. By installing this heating system first in one house, the district heating company and the family living in this house could show the rest of the households how the installation would look, with pipes and all. This household was included in the 13 households that had converted to district heating. Complementing questions about the demonstration was posed to this household.

5.5.2 Interviews

The interviews were carried out during four days in September and October (21/9 –22/9 2005, and 6/10-7/10 2005). Twenty-one of the 23 interviews were carried out at the interviewees' homes and two of the interviews were made over telephone. Twenty of the interviews were recorded and fully transcribed, in the other three notes were taken during the interviews.

The qualitative approach in this study aims at investigate how the respondents thinks about and experience the different activities in the district heating expansion process and not to how things really *are*. The advantage of this approach is that, in contrast with questionnaire studies that have been carried out to investigate customer preferences regarding different heating systems, the respondents are given the opportunity to describe their own reasons and their own situation. In questionnaire studies or in very structured interviews with given answer alternatives postulates for example that (Lantz, 1993):

- words have the same meaning for all people
- all people can place themselves in a category or on a scale
- the studied phenomenon has a meaning and a similar meaning to all people
- all respondents get the same question, that is exposed to the same stimuli and that is experienced in the same way.

This makes it hard to use a questionnaire when the aim is to understand what the households base their decisions on to approve of, or reject, the offer of district heating; the decision is part of a process and an interaction between the household members, something which is usually better elucidated in semi-structured interviews. In this decision-making process, information and other stimuli are perceived from different sources and are viewed from earlier experiences and representations. In the semi-structured interview it becomes easier to lead the interviewees in to speak about the decision process that has been going on in the household. In seeing that the households are going though a process when they make the decision whether to accept or reject the offer of district heating, the starting point in the interviews has been to make the respondents to tell their own story of what happened when they first got to know about the offer. By this way, the respondents have been guided to describe an episode, as they remembered it, and hereby we hoped to avoid posing direct questions in the initial part of the interview that lead the respondents to rationalise their answers in constructed logic. However, the respondents own dictum has been followed up by directed questions based from the constructs of economy, environment, comfort, need for control, captured customer and so on.

The interviews were carried out three to four years after the district heating company made the expansion into the area. This means that the respondents can have forgotten what they thought or how they reacted or reasoned at the time for the expansion. This is inevitable, but the respondents were, when they did not recall all the activities in the sales process, reminded by the interviewer. The time gap between the interviews and the expansion is at the same time an advantage. This gives the converted households the possibility to evaluate the heating system and to see the consequences of their choice in terms of comfort, technical functionality and economical aspects. Also the households that did not convert to district heating had the possibility to reflect over their choice. In the contact the neighbours that had converted, they also got the opportunity to compare how it would be if they decided differently.

The subject of analysis in this study is households and not individuals. Most of the interviewed households consisted of at least two adults. By practical reasons, the households were given the possibility to decide if one or both adult should participate in the interview. In some interviews only one person in the couple was interviewed, and this person has then represented the whole household. In these interviews, is was often the man who participated in the interview. A plausible reason for this is that heating systems are regarded a male-dominated area.

5.5.3 Statistical analyses

Some statistical analysis has been carried out based on the data attained from the municipal directory and VEAB's customer file. The analysis has been made for all the 111 households in the expansion area and this means that the results from these analyses can be generalised for the whole area.

To generalise these results outside this conversion area, some caution must be taken considering the specific prerequisites of the district heating company VEAB, the households and the geographic area.

Interviews and statistical analyses used in combination proved to be a valuable approach since some quantitative results could be intrepreted through information gained in the interviews. For example, the result that older households were not as inclined to convert to district heating as younger households, could easily lead to the assumption that older households are more reluctant to changes than younger ones, hence posing an attribute of passivity to older households. In the interviews, however, it was shown that older households had been more active in changing their previous heating system or water heater and therefore they had no real need to convert their (new) heating system to district heating.

6 Electricity peak load problems and load management in households

This chapter starts by giving a short introduction of the power peak problems that sometimes occur in electricity systems, emphasising on how these problems look like in the Swedish system. This is followed by some explanations of the different strategies occuring on the demand-side. The load patterns of households is touched upon in chapter 6.3, and chapter 6.4 discusses direct load control in households by discussing results from the load control experiment described in Paper IV. Finally, chapter 6.5 takes up the issue of load management through tariffs.

6.1 Power peak problems

Peak load problems are typical problems in all large technical systems, just imagine the traffic congestion in to or out from cities in the morning hours or evening hours. (For this kind of peak problem the word *gridlock* is a felicitous and suggestively term!).

The peak problems emanate from an uneven usage pattern in the system or in parts of the system and occur in narrow parts of the system, bottlenecks, or due to the lack of volume (or resources) needed to supply the demand. In electricity systems, bottlenecks can be avoided through expansion of the transmission capacity. To solve the problem of volume, storages could have been used if it were not for the specific physical nature of electricity that makes this property impossible to store[38]. Because of this, the electricity must be produced at the same time that it is used. Thus, a flexible power production with reserve power plants that can be started quickly, typically gas turbines or oil condense power plants, is necessary

To cope with peaks in the electricity grid, transmission capacities and production must be dimensioned on basis of the load pattern in the grid with regards to power peaks in the system. Therefore, it is easy to understand that an uneven usage pattern - a low load factor (see chapter 6.2), would be disadvantageous since this would require higher transmission and production capacity. Long-term and short-term economic problems with power peaks are described in Table 7.

Table 7: Different types of load problem.

	Short term economic consequences	Long term economic consequences
Problems with insufficient electricity production	Need to start expensive reserve power	Need to invest in new power plants (reserve or base production)
Problems with insufficient transmission capacity	Penalty for exceeding subscribed load level	Need to invest in grid reinforcements

[38] Potential energy can however be stored, for example in water magazines.

Peak load problems also have environmental impacts. Except from the obvious environmental advantages in avoiding increase in production and the building of new power plants, the quick start-ups of reserve power often require burning the fuel at a sub-optimal temperature, and sometimes without generating electricity. Additionally, ramping, i.e. changing the output from a generating unit, may cause fuel to be burned sub-optimally (Abaravicius, 2007).

Peak load problems are often discussed at a national level although many actors have different incentives to solve peak load problems at the local or regional level. Peak load problems at the national level occur rather seldom, whereas economic problems occur much more often for the local actors, i.e. the power-trading companies or the local network owner. In Sweden, local utilities pay fees to the regional network owner according to a load tariff. If subscribed load level is exceeded, large penalties, especially during weekdays when industries are fully running, are charged. The start-ups of reserve power capacity are also related to high costs. The reserve power often consists of gas turbines or oil condense power that have significantly higher variable production costs than hydropower or nuclear power. In Sweden, the costs can be up to 10 to 15 times higher (The Swedish Energy Agency (2003).

6.1.1 Electricity use and power production in Sweden

The electricity use per capita in Sweden is very high; only Norway, Canada and Iceland use more electricity per capita. Between the years of 1970 and 1987, the electricity use increased with 5% per year on average. After this, the electricity use has increased in a more moderate level of 0,3% each year on the average and levels around 146 TWh per year. The electricity use can be divided into three sectors: the industry sector, the transport sector and the residential and services sector, where the residential and services sector stands for nearly 40% of the electricity use, and transports for only 2-3% (The Swedish Energy Agency, 2007).

The electricity production varies with the electricity use. This means that the production in Sweden is high at wintertime and low at summer time, due to the large part of electricity that is used for heating purposes. This makes the electricity production literally weather dependent. The main part of the electricity production in Sweden is based on nuclear and hydropower, 46% and 44% respectively in 2006, and the remaining production comes from fossil and biofuel based production, and to a small share, from wind power (ibid). The production form hydropower depends on the precipitation and the filling of water basins mainly located in the Northern parts of Sweden. The production from hydropower is generally about 65 TWh, but it has been seen to vary between 51 to 79 TWh in exceptionally dry or wet years (The Swedish Energy Agency, 2004). At dry years, hydropower production decreases and the electricity supply in the country become more dependent on other domestic sources or on import from neighbouring countries.

After the deregulation of the electricity market, the power reserves in Sweden have decreased. In order to cope with peak loads, the Swedish national grid operator was assigned from the Swedish government to stockpile a production reserve of maximum 2000 MW between the years of 2003 and 2008. After this, it was meant that load problems requiring the use of reserve power should be solved through mechanisms on the market. This has however not happened, and Svenska Kraftnät has now got a prolonged commitment to stockpile reserve capacity for three more years, until March 2011[39].

[39] Source: Svenska Kraftnät: http://www.svk.se/web/Page.aspx?id=5595, downloaded, 7 May 2008.

The start-up of expensive reserve power plants is an economic question not only for the utilities. In fact, power-trading companies have the possibility to take the addidional costs out on the customers. However, competing prices are a very important factor when customers chose from which power-trading company to buy electricity from, and from this perspective the high production costs are not good for competition. In some occasions, the price cannot be taken out on the customers, such as in case of fixed contracts or if there is a ceiling put on the electricity tariffs – something that happened in California in 2000, where utilities had to pay vast prices for the load reserve without having the possibility to charge the customers accordingly. Moreover, incresead prices are a national economical matter because it affects private economy in households as well as the electricity dependent industry, for example the pulp, steel or chemical industry which are important industries for Swedish export.

Thus, by looking at the development of electricity use and supply in Sweden, it seems that an increase in demand is meet by a decrease in production, and that there are several reasons to look for solutions at the demand-side.

6.1.2 Transmission capacity

The national electricity grid was built and dimensioned in terms with the electricity demands that exist due to the specific geographical localisation of producers and users in the grid. This means that the direction of transmission usually goes from the north to the south of Sweden, since the hydropower stations mainly are located in the north and most users are located in the south. In the grid, there are four narrow sectors in particular, where bottlenecks can arise (IVA, 2002a).

Bottlenecks can cause deficiency of electricity on one side and surplus on the other side. The bottlenecks are either temporary or structural. The temporary ones appear more seldom and may be the results of maintenance, technical problems or specific market conditions. Structural bottlenecks are a result of how the power system is built and where the producers and users are located in the system (Nordel, 2004). Physically, a bottleneck can only be dealt with if electricity producers in a surplus area adjust their production to the actual demand, and producers in a deficiency area increase their production. Correspondingly, the users can lower their electricity demand in the area of electricity deficiency, and increase the demand in a surplus area (ibid). There is no regulated responsibility to ensure constant capacity (Svenska Kraftnät, 2004a).

Between Sweden and the neighbouring countries there are several transmission links, especially to the other Nordic countries, but also to Germany and Poland. The overseas transmission capacities have increased in the later years according to the Swedish national grid operator and it is very rare that these transimission capacities are deficient, even in high-load situations in Sweden (Svenska Kraftnät, 2004b). More reinforcements of the links between the Nordic countries are also planned. This will make the Nordic electricity system more robust and also contribute to increased competition and the equating of the electricity prices between the Nordic countries.

6.2 Load management

Load can be saved or altered by using different strategies. Electricity utilities often have an economic interest in making the coincident load pattern from all customers or a group of customers as flat as possible, in order to enhance system efficiency and to avoid penalties or expensive investments.

The load factor is one way to measure the flatness of the load curve, given in equation (1).

$$\text{Load Factor} = \frac{Load_{average}}{Load_{\max}} \qquad (1)$$

The load factor is simply the ratio of the average load during a specific period of time to the maximum load occurring during that period. The load factor can range between 0 to 1, where the value of 1 indicates a completely flat curve without peaks. (More methods to analyse load are showed in Paper VI).

Six different ways to modify the load pattern are emphasized by Gellings (1993), see Figure 4.

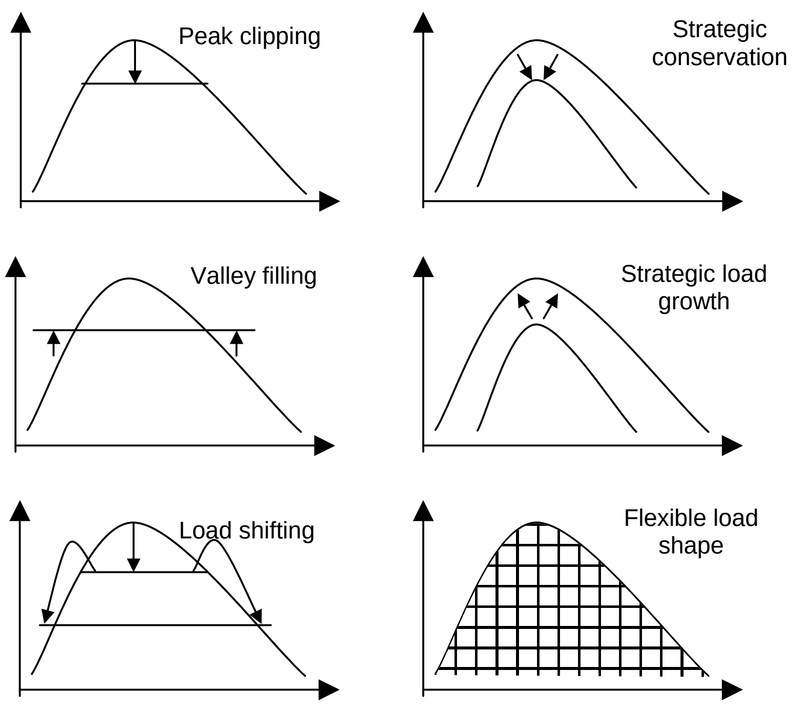

Figure 4: Load control strategies (Gellings, 1993).

The strategies showed in Figure 4 could be described in the following way (as cited from Abaravicius, 2007, p.21):

- Peak clipping – reduction of load during short usage peaks.
- Valley filling – building loads during the off-peak period.
- Load shifting – combines the benefits of peak clipping and valley filling by moving existing loads from on-peak to off-peak hours.
- Strategic conservation – decreasing the overall load demand by increasing the efficiency of energy use.
- Strategic load growth – increased electric energy use either to replace inefficient fossil-fuel equipment at point of use or to improve consumer productivity and quality of life.
- Flexible load shape – specific contracts and tariffs with possibilities to flexibly control consumers' equipment.

Additional ways to influence the shape of the load curve are *energy savings*, where for example the shifting of light bulbs to low-energy bulbs can decrease the load from lighting; the *change of energy carrier*, for example to convert electricity heated houses to district heating (as discussed in chapter 8), or *self-generation*, for example the use of photovoltaic panels on the roof that could either be distributed to the electricity network and bought back, or be used directly in the home.

Load management can be divided into two categories: *direct* or *indirect* load management. Direct load management is a conscious limitation of the load consumption carried out by the energy users themselves or by the utility, for example through remote control. Indirect load management can be seen as an aimed intervention of the load demand either through pricing using different types of tariffs, abatements or contracts; through a system of rules – laws, regulations or incentives; or through information (Pyrko, 2004). In other words, the customers' load demand is modified by an automatic mechanism through technical control or by giving the customer incentives to alter its load pattern by using the energy in a different way or to shift the load to other periods. The willingness or acceptance from household customers to do this has been tested in some of the studies in this thesis.

But why use load management in small residential units when larger customers could shift much more load? Detached residential houses in Sweden comprise a large part of the residential building stock. The dominating energy source for heating and domestic hot water for these houses is electricity. Under current dominating pricing conditions (tariffs, etc.) in Sweden the customer is not encouraged to use load optimally. However, the electricity suppliers, having already to some extent used the load management potential in the industrial sector, consider the residential one as a significant potential for load management. There are several examples of direct load management systems, used in residential houses both in Sweden and other countries.

Moreover, the domestic electricity use has continuously increased in the last decades. The slope has flattened the last decade, but there is still an up going trend. In 1970, an avarage Swedish household in a detached house used about 4000 kWh per year for domestic electricity use. Today the electricity use is close to 6000 kWh per year[40]. This increase can be explained by the increase in the possession and use of electric appliances (Bladh, 2002).

6.3 Patterns of electricity use in households

The pattern of electricity use in a household is to a very large degree dependent on how the household members organize their everyday lives. As argued before in chapter 4.1.3, there are different restrictions that influence how we organize our everyday life (i) restrictions from authorities and means of control, (ii) restriction through interaction with different members in the household or immediate family, and (iii) restrictions that is due to deficient capacity where for example physical restrictions are highly influential in how we use our time, i.e. the need to sleep and eat at certain times. By the use of energy, we have altered the prerequisites for the organisation of everyday life. With lighting we can now perform work also at evenings or working night shifts in industries, and with the use of a standardised indoor climate (as posed by Shove, 2003), we can now carry out work or activities that we would not be able to do in the coldest or hottest days or periods in some of the days. Energy is thus changing some of the restrictions in everyday life, which in turn are changing load patterns.

Where the questions of *how* and *why* we use energy are commonly stated in many behavioural energy research studies (maybe the most common question stated is *how can we influence households to save energy?*), the time use aspect of the energy use is not developed or investigated, i.e. stating the question of *when* energy is used and why these patterns occur. In all large technical systems with peak problems, it would actually be valuable to tie the organisation of everyday life to the patterns of use in order to see if something can be changed to prohibit the problems.

In society some concerns are taken to solve peak problems even without a closer investigation of usage patterns because the problems are so apparent. Take for example the winter sports holiday for schoolchildren that nowadays is celebrated at different weeks in different schools in the country in order to avoid overload at winter sports facilities and hotels. The owners of these facilities can not cope with too many guests at the same time, nor will they have the money to enlarge their business just to serve an increased demand for one or two weeks per year. In other countries it is very common to have different time schedules for summer vacations in order to decrease the problems with crowded means of communication or heavy traffic.

But for energy use, the traditional way to respond to the increase in demand and to peak load problems has been to increase the supply and to enforce the transmission capacity. This can however not be said to be the *sustainable* way to solve peak load problems in the electricity grid today.

By knowing what activities and what appliances that mostly contributes to peak load problems, it becomes easier to find a solution to these problems within the households. To know more about everyday life in households also help to avoid management control measures or price mechanisms that will have a strongly negative impact on the households or to some members of the household. For example, by knowing that women still are doing the greater part of many of the domestic tasks in the household, it would be clear that the use of

[40] Source: SCB (Statistics Sweden: www.scb.se/templates/tableOrChart_20407.asp, downloaded 2004-10-13.

time-tariffs may further increase the stress that women experience and the sense they have of the pace of life speeding up. To put the social practices of households in the centre of a model in between the systems of provisions and the users (like in the model of social practices by Spaargaren and Van Vliet) appears to be a good idea when it comes to developing new measures of demand-side management.

6.3.1 Measured partial loads in 10 households

One common way to categorise the electricity use in households is to divide it into electricity use for space heating, for hot water preparation and for domestic electricity use – at least in Sweden, where there is a large share of houses that have electric heating as their main heat source. Space heating and hot water preparation are then included together with the domestic electricity for lighting and appliances as a total sum on the electricity bills, since there are no electricity meters measuring each load separately. In the studies in Paper IV and V, this was however done after the utility had installed two extra meters in each of the ten households that participated in these studies. In Figure 5 on next page, the electricity use, divided in the three loads is shown for the ten households for one day in December 2003. For information about the households, see Appendix B.

As can be seen in Figure 5, the load curves from the ten households show substantial differences in terms of the different loads. The 23d of December is a special day in Sweden, since it is the day before Christmas Eve. It is usually a day with quite high load, because of the different preparations made for Christmas, especially in terms of cooking. It is also a cold winter day, and for this particular day, the outdoor temperature varied between –9ºC in the early morning and 2ºC in the evening. Household 6, 7, 8, 9, and 10 had smaller houses than the other five households, which clearly shows on the heating load. Household 10 was the one with most household members and this households' load for domestic electricity and electricity for hot water preparation is typically larger than in the other households.

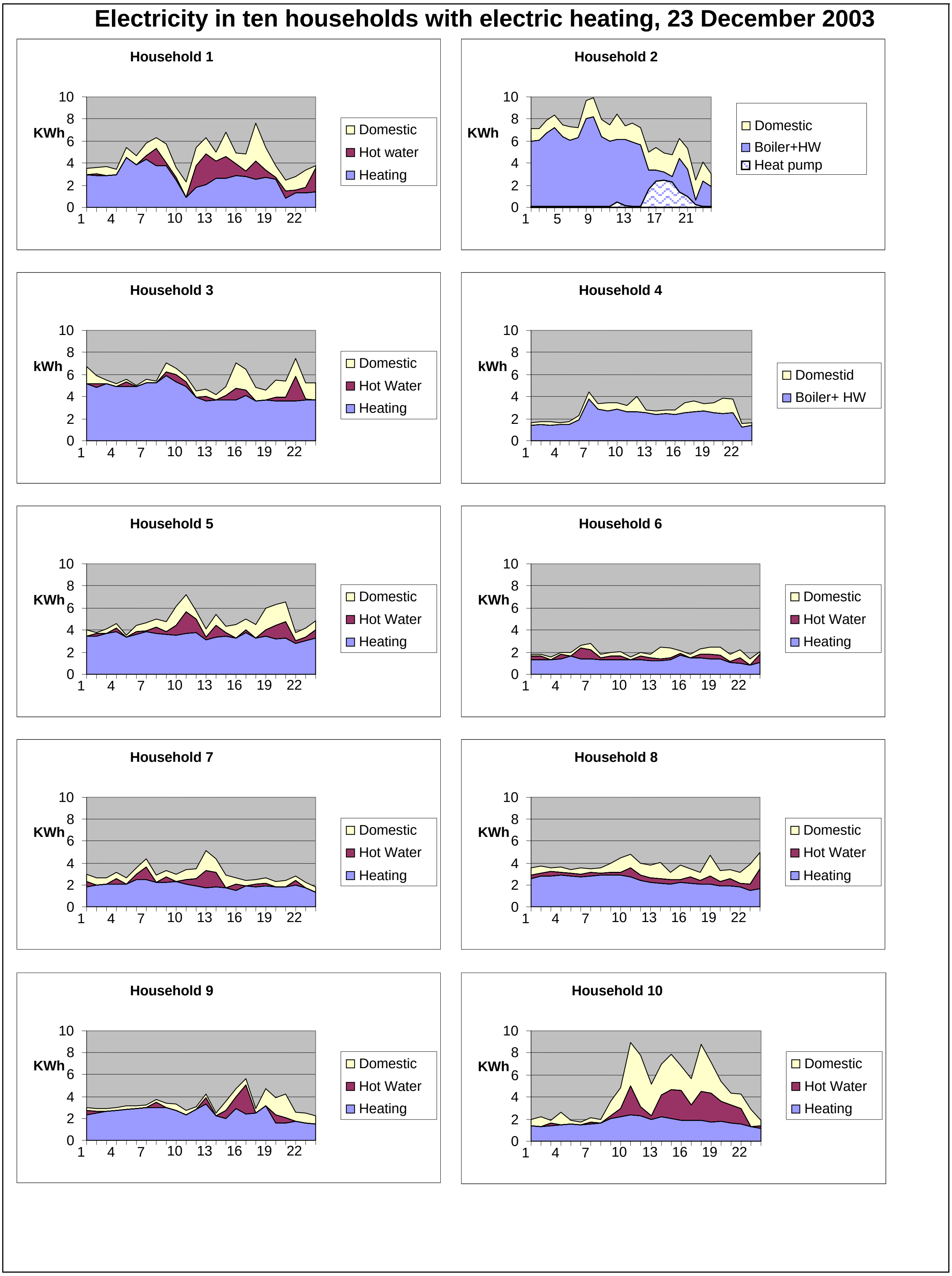

Figure 5: Electricity use in 10 households in Scania, 23 December 2003.

In Table 8, an overview of factors that contributes to the differences in electricity use is shown.

Table 8: Factors that influences the different load patterns in the ten households.

Building	Type of building	Three houses are semi-detached and seven are detached houses
	Construction	Brick construction with framework in wood or light concrete Extra insulation in some houses
	Construction year	1961-1978
	Living area	The living area varied between 95 to 186 m^2, or up to 300 m^2 if heated basement was included
Installations	Type of heating system	Waterborne of direct resistive electric heating. Some household use fireplaces or stoves. Air to Water heat pump in one household
	Type of installations and larger equipments	Electric radiators and automatic control systems differ between households. Some had ”soft” heating systems with load guards. Most systems had outdoor sensors. Permanent installations of saunas or floor heating were found in some households. The possessions of electric appliances naturally varied between households
	Age of installations	Varying, for example the age of freezers and refrigerators
Climate	Geographical location, climate zone	The households lived within a radius of less than 1 kilometre
	Outdoor temperature	The temperature was the same for all the households, but it naturally varied during the period of measurements
	Solar radiance and wind	Bield and shadow from vegetation varied for the different households, due to different locations
Socio economic factors	Household members or users	One to four persons
	Absence from home	In some households the residentials were absent from home during daytime because of work or school. Other were at home at most times (mainly pensioners or parents on parental leave)
Behaviour	Life styles and behaviour	Differed between households (to some extent investigated in the diary study and the interviews)
	Seasonal and daily changes of needs	Need for lighting increases in darker seasons and the heating need increases with colder temperatures. Some differences in time when the households turned on the heating system in the autumn and shut it off in the spring were noticed.
	Indoor temperature level	Indoor temperatures varied between 18-24.5ºC in different households during the period of measurements. Some households used the possibility to lower the temperature in night-time, or deliberately keep lower temperatures in some rooms

As can be seen in the different diagrams in Figure 5, the heat load makes up for the largest part of the total load pattern of the households and heat load is in general (as argued before) a large contributor to peak problems in winter-time in the Swedish electricity system. But it is in combination with the load from domestic electricity and hot water preparation that the highest peaks occur in the households. Utilities typically have problems in the mornings or evenings when many households are carrying out the same kind of activities, for example take a morning shower or cooking dinner. In the diary study, one analysis was carried out on what appliances and activities contributed to the highest peak load in the households during the diary period. The analysis was based on the measurements on the three partial loads and the notes from the energy diaries. The results from this analysis are showed in Figure 6.

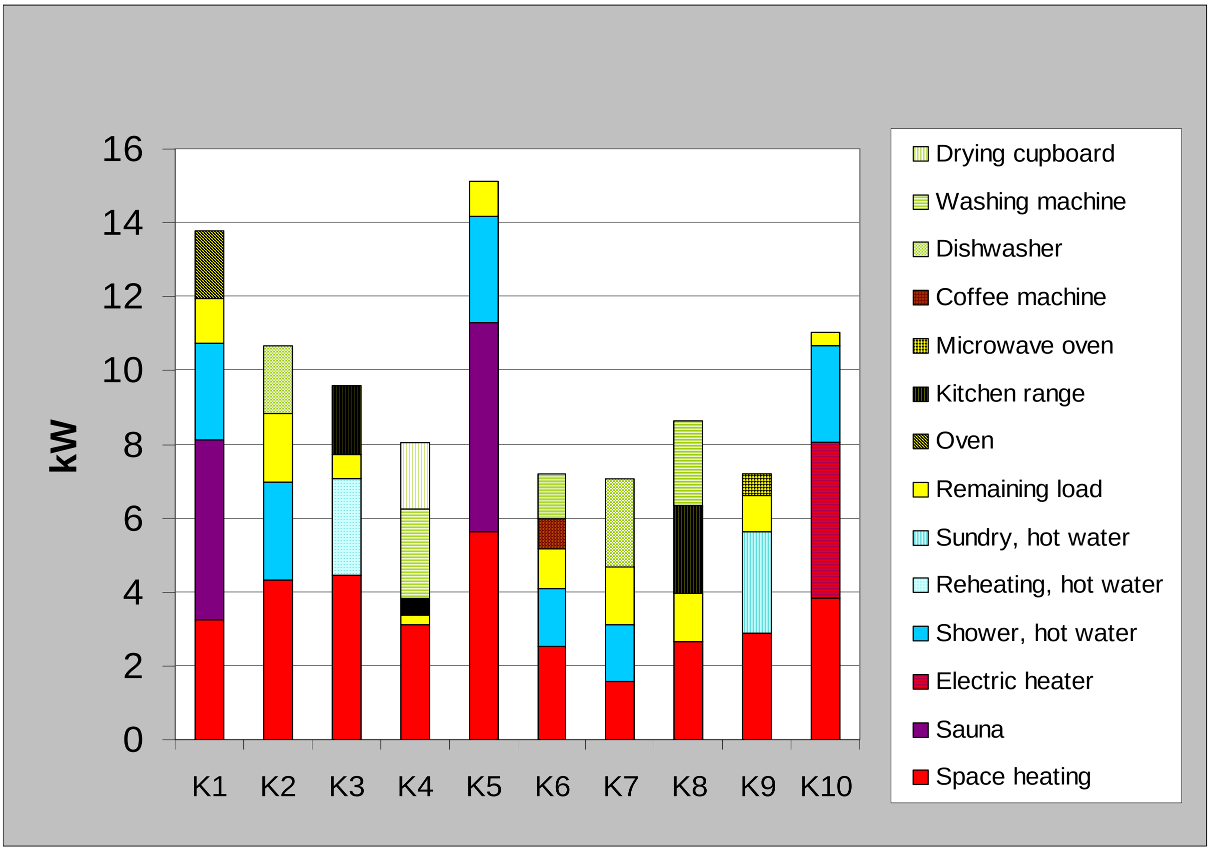

Figure 6: Type of electricity use that caused the highest peak during the diary period.

The heat load lies as a base load in the bottom of the staples. It contributes to between a third or a forth of the load in the highest peaks. In eight of the ten households the load from the water heater contributes to the peak. In six of these cases, the households have taken a shower, in one case hot water has been used for other purposes and for one case the water heater thermostat has started the heater for keeping the temperature level in the heater. In household K1 and K5 the sauna was used at the time for the highest peak and in the other cases it is the use of appliances for cooking (oven, stove, microwave oven or percolator); or either the dishwasher, the washing-machine or drying cupboard has been used. For the remaining load, the base load of freezers, refrigerators, lighting and stand-by is intended.

The load from freezers, refrigerators and stand-by power forms a kind of base-load in the domestic electricity use that cannot be explained from activates that are taken on by household members. This 'base-load' varied from 250 W to 1,250 W in the households. Although 10 households is only a small sample, these results show that there can be large variations between households. On a yearly basis this would mean that these households range between 2,190 kWh to 10,950 kWh which in turn will have considerate impact on the in electricity costs for the households with the highest shares. This also shows that behaviours like overhauling the stand-by power usage in the house or replacement of old freezers or refrigerators really can save a lot of electricity and money and decrease the total power load in the household.

6.4 Previous studies of direct load management

Direct load management, where utilities control the load at customers in premises and in detached houses, was tested in some pilot-projects conducted by the largest electricity utilities in Sweden (Vattenfall and Eon, former Sydkraft) in the late 1980s and the early 1990s (Sydkraft 1988; Sydkraft 1989; and Vattenfall, in Levin & Wesslén, 1993). In the detached housing sector about 450 pilot installations were tested in town of Värnamo in houses equipped with direct resistive electric heating (Sydkraft, 1989). The objectives were specified to the wish to investigate different technical and economic conditions for large-scale installation, and to evaluate technical performance and coincidence load reduction in grid sub-stations. Another aspiration was to investigate the inclinations of customers in detached houses to participate in a load control system. This was done by a questionnaire that was sent out to selected housing areas. The interest to participate was large; almost 65 % of the invited households wanted to partake. When it comes to household experiences and attitudes of the load control system, only the very installation phase was examined and there were no inquiries about how these households experienced their thermal comfort during the control periods or what attitudes they had to the fact that their load was managed from outside, from the utility during these periods. Therefore, this study does not give much information on how people adjust themselves to the load management or their acceptance of it when they have had the chance to evaluate it over time.

Several tests of load control in residential areas have been carried out within Vattenfall's research project "Uppdrag 2000" (which means "Mission 2000"). In some areas load control of electric heaters were investigated in 127 flats and 136 twin-houses (Levin & Wesslén, 1993). The aims of this project were to investigate the potential load savings of load control and to see what consequences the load control had for the residentials' thermal comfort. The results showed load savings of about 1,8 kW per house at outdoor temperatures of between 0 and 2ºC. The recovering load[41] was estimated to be approximately in the same size as the load savings. The impact from load control on indoor thermal comfort was demonstrated only as decreases of temperature levels in the households. The temperature levels typically were lowered by 1ºC for control periods of three hour. No other factors of thermal comfort levels were investigated. In one housing area a trivaricate tariff was also tested. The tariffs' three parts consisted of a conventional time-tariff (a tariff with high and low tariffs) and a special tariff with a higher electricity price for the load control periods. A red light, placed in the hallways, was used to show the residentials when control periods were on. Two questions were asked to five customers: Do you notice when the red light is on? What are you doing then? The answers from the households showed that:

- In house 1, they avoided the use of the dishwasher and the washing machine when the light was on.
- In house 2 they avoided the use of the dishwasher.
- In house 3 the red light was not noticed (because the light was hidden behind a door).
- In house 4 they did not react on the red light.
- In house 5 they surveillanced the lamp and they avoided the use of the washing machine, the dishwasher and the tumble dryer, and switched off some lights.

[41] Recovering load is the load that follows from a load control or shut out of a system. The increase in load depends on that the system is trying to retrieve the temperature loss due to the shut out.

In this study, they combined the direct load management with price-signals, i.e. indirect load management, which is an interesting approach that is going to be touched upon in chapter 6.5. In the five households it was manly the load from doing laundry or from turning on the dishwasher that was moved to other times with lower tariffs. It would have been interesting to know what the households thought when they choose to change (or not to change) their behaviour when the red light was on. Was the" sacrifice" made because the household wanted to save money or was it because they wanted to help the utility in times of high loads? Was the economic saving worth the trouble? Why did the households mainly choose to shift the loads from dishwashers and washing machines, and not other electricity use? Was it because they did not know of other possibilities or was it because they thought that these activities were the easiest ones to move?

Another example of load management projects was carried out on in New York, the USA. The programme is still running today according to the web page of LIPA[42], from which a brochure about the LIPAedge programme can be downloaded. Long Island Power Authority (LIPA) is distributing electricity to 1,1 million customers in New York. LIPAedge is one of LIPA's load reducing programmes that are directed to customers with central air-conditioning or swimming pools. A central thermostat unit to the cooling system is given to each customer and through this, the utility can control or regulate the cooling system or pool pump, or the customers can remotely programme the system through an e-mail service. The customers are noticed about the control periods in advance and therefore they have the possibility to override the utility control signals. LIPA has committed to limit the control periods to maximum 7 days in the summer. In this area, most peak problems occur in the summer time due to the cooling demand in residential houses and premises. In 2003, there were 26.000 households that participated in this load control system, but earlier LIPA had problems with getting households to participate and as much as 45% of the households choose to override the control signals from the utility. An investigation was made to find out the reasons for this, and the results form this investigation showed that many households did not understand the concept of the load control system and did not know that they had overridden the control signals from the utility. New information was developed and after that these problems decreased and totally about 26 MW could be shifted within the LIPA programme (Johansson, 2003).

A study of load reducing equipment that can be remotely controlled from a utility, and that actually focus on household experiences of the technology is Margrethe Aune's survey about the E-box (Aune, 2001). The Ebox is an electronically control unit connected between the source of current and the electric appliances that are going to be controlled. The households with access to the internet could regulate their indoor temperature remotely, through a web module in the equipment. The households that did not have access to Internet could preset the temperature manually on the Ebox. The utility also had the possibility to do these settings remotely. The Ebox was introduced in a pilot project to 17 flats in Oslo. The households constituted a heterogeneous group, where some of the households had Internet access and some had not. After six month with the Ebox, the households were interviewed. The theoretic approach in the interviews was based on the constructs of design/function/control, usage patterns, motivation and communication. One interesting result from this Norwegian study was that the participating households actually did not focus that much on the utility's possibilities to control the indoor temperature, but more on the own possibilities the Ebox gave the household to control the temperature level in the dwelling. That the households were

[42] Source: http://www.lipower.org/efficiency/lipaedge.html, downloaded 9 May 2008.

aware of the utility possibilities to control the load was, however, clear when the costs for the Ebox were discussed. Some households, the ones that Aune calls “The enthusiastic”, did not expect any rewards from the utility when giving the company the control over their indoor temperature level. On the other hand, these households did not want to pay for the Ebox, because of the benefits from the load control possibilities for the utility. Other households, with a more individualistic attitude (the sceptical), wished to see rewards in terms of lowered grid fees. These households meant that the utility could earn a lot of money in avoiding the investments of grid reinforcements. The Ebox should naturally be free of charge.

Other examples from Norway, where load management is carried out for households customers, for example the cooperation between the research organisation SINTEF, the trade organisation EBL-kompetanse, the Norwegian University of Science and Technology and the utilities Buskerud Kraftnett and Skagerak Energinett. There, AMR with load control functions are tested at 10 000 household customers. In Denmark the utilities Eltra and Elkrafts have implemented load control at 25 customers. The customers were promised about 1000 DKK in compensation.

Research and projects about load management in the residential sector have been carried out for some decades now. The technical possibilities are constantly changing and it is naturally both important and relevant to continue with technical and economic updatings and reports in this area. What this research fails to emphasize is the household customers’ attitudes, experiences and acceptance of different load management measures. The comfort aspect is a really important one – to see what is happening in the households and how this affects the everyday life of households.

6.5 Direct load management in collaboration with a Swedish utility

In the years 2000 to 2005, the research group in Energy Efficient Buildings had a close cooperation with the Swedish utility Skånska Energi AB, that was one of the first utilities in Sweden to measure electricity on hourly basis at their household customers through their AMR system CustCom.

In 2003 and 2004, studies of indirect and direct load management were conducted in ten households in the village Södra Sandby located in the utility’s electricity grid. Power load was measured for three different loads in the households, namely for the electric water heater, electric space heating and total electricity use, enabling calculations of domestic electricity use on hourly bases as well.

A load control experiment was carried out in the ten households where the heating and the hot water systems were shut off and turned on remotely using the CustCom system. The methods of the load control experiment are described in chapter 5.2.4. Some results from this study are shown in Paper IV, both technical and behavioural. However, in the next chapters of this thesis there will be a focus on the behavioural aspects of direct load management, since this is an uncommon approach in most load management studies.

6.5.1 Motivational factors for the utility

The utility’s interest in load management emanated from wintertime peak problems, usually on weekday mornings and holiday (weekend) afternoons since the majority of the utility’s customers have electric space heating. Daily peak demands, during morning and evening hours, together with higher heat demand due to outdoor temperature drop, cause risk to exceed the subscribed load for the grid company. This results in penalties from the higher-level network owner Sydkraft (now Eon), and thus significant economic losses. The utility would benefit economically by securing the load below the subscribed level and by decreasing it. The utility has some few alternatives to solve this economic problem: To apply direct load management using the remote metering and control system CustCom; to introduce a new pricing with a load demand component, or; to install diesel peak power plant with 2-3 generators with a capacity of 4 MW each. The last alternative would contribute to significantly higher CO_2 emissions, since diesel power plants have one of the highest emission factors per fuel, 1056 kg CO_2/MWh (Meyers, et al), which can be compared to the average emissions from CO_2 in the Swedish electricity system that is around 12 kg CO_2/MWh.

6.5.2 Long johns on, but the tulips are fine!

"Long johns on, but the tulips are fine!" was a comment written in the comfort sheets in one household, showing that the household noticed a specific load control period. The most important findings about household thermal comfort from the study will be presented here.

The electric heating systems were remotely controlled by the utility through an on/off regulation. The load experiment was designed as a blind test, to test if the households would notice when their systems were controlled. The control periods were planned in a specific schedule that was given to the utility. Table 9 shows the number of controls and the length of the control.

Table 9: Control of heating systems.

Length of control	Number of times
1 h	5
2 h	7
3 h	4
4 h	3

As argued earlier, the thermal comfort is an individual experience of the satisfaction with the thermal environment. The thermal comfort includes the factors of air temperature, radiant temperature, air velocity and humidity, clothing insulation and metabolic heat. The first four factors refer to the physical environment and the two latter factors relate to the person itself. Only one of these factors was actually measured in the study, the air temperature, but the others were touched upon to some degree in the interviews.

Average temperature level and adjustments to temperature

The average temperature levels varied quite significantly in the ten households, see Figure 7.

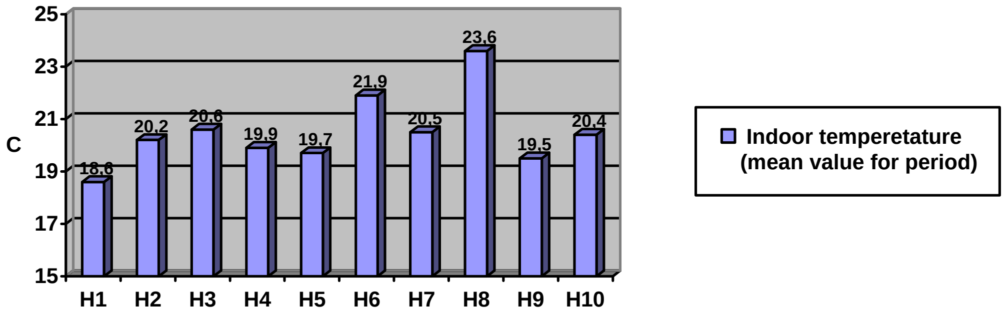

Figure 7: Average indoor temperature in the ten houses during the test period.

The average indoor temperature in the households varied between 18,6ºC and 23,6ºC. Different opinions of what temperature level is the most optimal were shown in the interviews. Some persons really did not like to stay in rooms with a temperature level of 23, 24ºC, whereas others said that they easily freeze when the temperature goes down below this level. It also became evident that the persons adjusted their clothing to the temperature level. In the households with lower temperatures, the household members compensated the lower indoor temperature with putting on an extra sweater and some slippers on the feet. In the household with the highest temperature level, the household members often wore shorts and T-shirts even wintertime. In some households fireplaces where used as an additional heat source.

Temperature drops due to load control

For longer control periods the temperature drops reached down to 2,5 °C at most, but in general the temperature drops were lower (see paper IV). The outdoor temperature for the test period was relatively high for the season, between –0,8 °C to 6,1 °C (in average 2,1 °C).

The recommendation from ISO Standard 7730 on the operative temperature level[43] is that it could vary between 20ºC and 24ºC. The temperature gradient, measured 0,1 m and 1,1 m over the floor, should not exceed 3ºC, and the temperature on the surface should range between 19ºC and 26ºC. These are the recommendations. If a household keep an average temperature level of 19ºC and the load management of the electric heating system leads to a temperature drop of 2ºC, the temperature level would actually come down to 17ºC, which is under the recommendations. For households that keep an average temperature level of 23ºC, this level would not be exceeded.

Sensitivity to temperature drops

Results from the study show that it was not so much the actual temperature level that caused inconvenience, but the rapidness of the temperature drops. A fast drop of temperature was more noticed than a slower. Moreover, households used to higher average temperatures showed to be more sensitive to these temperature drops than others. This can probably be explained by the fact that these household had adjusted their clothing to their high average

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[43] The operative temperature is a function of the air temperature and the radient temperature:

$T_{op}=(T_{air} + T_{rad})/2$.

temperature, and that they experienced cold draft on the floor since they often were barefoot. According to Ronge (1970), especially the feet are sensitive to draft or cold.

The rapidness of temperature drops is due to the weathers, the thermal characteristics of the building, the heating systems capacity of heat storage and the activities performed in the household. Households in houses that were built with lighter constructions were more exposed to rapid temperature drops since these houses do not storage heat as well as heavier constructions. Therefore, households in the latter constructions are more suited for load control of the heating system.

Additional electricity uses in the household might raise the air temperature. The households noted more control periods in mornings than in the evenings and this was probably due to the activities of cooking and to the solar radiation that heated the building during the day. Therefore, load control in the mornings may contribute to more inconvenience than load control in the evenings.

The load control experiment was made as a blind test. It was shown in the interviews and in the notes of the comfort sheets, that quite a few of the control periods where noticed by the households, in some households even the shorter control periods of one to two hours.

Loosing the control of the indoor comfort

During the load control periods, the utility turned off the customers' heating system. The households then loose the control of the temperature level in the house. Since the whole system is switched off, there are no possibilities to regulate the heat trough thermostats on the radiators. Some households reported that they felt uncomfortable not knowing when the heat would come back again. This indicates that it would be positive if the utility used some kind of signal when using of the load control possibilities, as the example in the study by Vattenfall exemplifies. If they receive a signal some households would perhaps decide to contribute to extra load shedding, by turning off some electric appliances or by delaying some activities, for example doing laundry or starting the dishwasher.

6.5.3 Domestic hot water comfort

Load shedding of water heaters were carried out in eight of the ten households. In the two remaining households, the water heater was integrated in the electric heater and domestic hot water and heating were thereby controlled at the same time in these households. Length of the control periods for the water heaters and number of times they were controlled is shown in Table 10.

Table 10: Control of water heaters.

Length of control	Number of times
1 h	7
2 h	4
3 h	2
4 h	2
16 h	1

The households did not experience any inconveniences whatsoever with the controls of the water heaters for control periods of one to four hours. The 16 hour long control period was made as a test on the sensibility of domestic hot water comfort. It is rather remarkable that only one of the households actually noticed this control. This household was the only one with four household members. This household also had a smaller water heater (200 litres) than some of the other households (see Appendix B). In the interviews it was shown that some of the households did not even think that the water heaters had been shut down.

It seems that the domestic hot water comfort is more robust for this kind of on/off regulation, especially if households are equipped with large water heaters that can serve as hot water storage. However, the disadvantage with load control or water heaters is the risk of having no load to save, since the water heaters only go on when hot water is used or when the temperature reaches under a certain level and the thermostat starts the heating again. Figure 8 shows the load pattern of a water heater in one of the ten households.

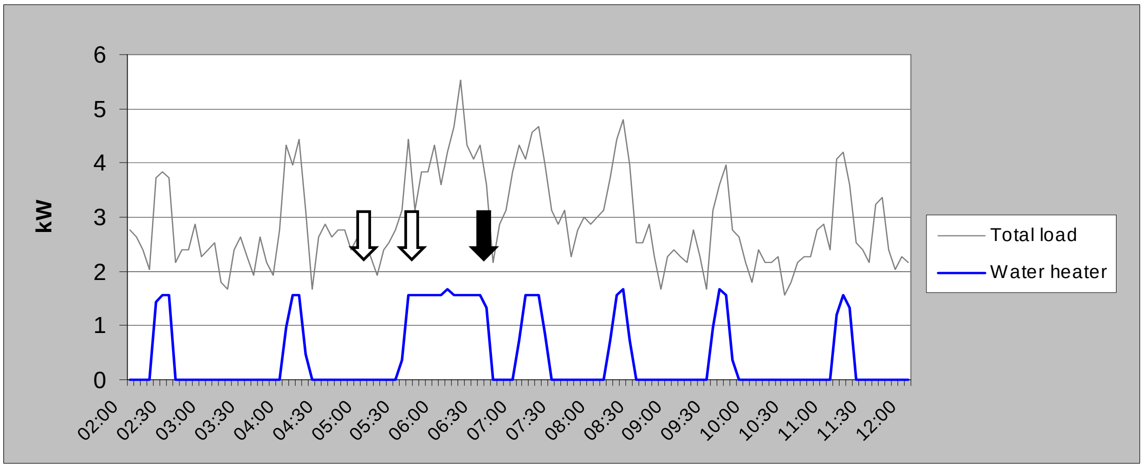

Figure 8: Load pattern of the water heater in household K6.

The white arrows indicate when the two members in this household took a shower and the black arrow indicates when the activity or washing the morning dishes took place. The other peaks in the curve refer to the thermostat-regulated reheating in the water heater. The typical load curves for hot water use are very different in the ten households. The highest probability to get load savings from controlling the water heaters in these households would typically be in the morning between 7 and 9.

6.5.4 Peaks and loads – not a sexy topic?

Chapells and Shove (in Chapells et al, 2000) argued that the language of peaks and loads may fail to interest many households. The truth is that many households probably are not aware of the peak load problems that occur in the electricity system (or in other large technical systems). In the interviews with the ten households, this became evident. Some households thought that the load management was due to save energy, not to shed load. These households thought that they actually saved money when the utility shut off their electric heating systems. They had never heard anything about recover loads that eats up the 'savings'. If households are to be persuaded to participate in future load control programs, they need to obtain information of why load management is a good idea. Also, they need to know the reasons to reduce the load demand at certain times. In knowing that the collective costs for electricity distribution can be lowered and negative effects for the environment can be avoided by load management, people can be motivated to participate in load management programmes.

6.6 Indirect load management through tariffs

The costs to produce and distribute electricity vary over time, depending on the production mix and on the volume of demand. Local utilities can either use bilateral contracts for their electricity purchases or buy electricity on the spot market. Utilities can engage in various risk strategies that depend on what type of contract they sign with producers (variable or fixed prices) or if the choose to buy from the spot market. The spot prices are known to vary and the buying and selling of electricity volumes or termines is now a business of its own. Different risk strategies in electricity purchases make the power-trading companies more or less sensitive to the economic consequences of peak problems.

Local network owners pay a grid fee to the higher-level (regional) network owner. This fee is also based on different tariffs, which in turn are based on for example seasonal or weakly variations of load. If the subscribed load level is exceeded, this can cause high penalties for the local utility. The tariffs are usually higher on weekdays when the industry is running and lower on weekends and in summertime. Therefore, there are many reasons for power-trading companies and local network-owners to use tariffs to their own customers in order to reflect the variation in the costs that they face in their own contracts and electricity purchases.

By not having any tariffs that reflects the variation in costs, there is no additional cost for customers to demand higher load from the grid. This cost should be shared with the company, especially in case of load shortages. On the other hand, customers “helping” to avoid load peaks in the grid should be rewarded in some way through the tariff.

In Paper II, the introduction of a new tariff with a load component was studied in the case of the Swedish utility Sollentuna Energi AB. Through this tariff, the utility wanted give the customers an incentive to care more about how electricity was used within the households in terms of load. Due to the imitated sample in the analysis, it is difficult to determine whether the new tariff had an effect or not for the general population in the network area. Representatives from Sollentuna Energi AB have in later conversations with the research group stated that they were able to see an effect from the tariff on the load pattern of the whole customer group. This, in turn, saved the utility from increasing the contracted level with their higher-level network-owner, which was what several other local utilities, closely situated to the Sollentuna area, had to do.

Results from the study show that all the customers saved money with the new tariff (between 3% and 20%), but only 6 of the 15 customers reduced their peaks of load demand. Customers with the lowest consumption experienced the highest savings in percent. This is however expected since the customers in flats only used electricity for domestic use and the customers in villas also used electricity for space heating and hot water preparation and these load are not as erratic as electricity load for domestic use.

An important conclusion from the study was that the load component was unnecessary in the summer since the utility does not experience any load problems at this season. The utility changed the tariff according to the objections from the research group after the study was finished. In order to achieve load savings in the coincident load pattern from the total customer group, it is important that the tariff reflects the experienced load problems. If there are no peak load problems in the summer time, why use an altered tariff at this period? Likewise, if there are no problems at weekends, then why include weekends in the altered tariff? Actually, the utility would probably better use the strategy of strategic load growth or valley filling, and not peak clipping at these periods (see Figure 4). From an environmental point of view, the strategies of valley filling or strategic load growth would (probably) not be desirable.

6.6.1 The customer's point of view

Until now, the tariffs have been discussed from a utility point of view, but what about the customers? What do they think about different types of tariffs to lower peak demand?

After all, the research group never followed up the case with the Sollentuna tariff with a behavioural study. The Swedish Consumer Agency did however a survey where the customers of Sollentuna Energi were asked if they were satisfied with the new tariff. The result was clear: over three quarters of the respondents in the study preferred the old tariff.

This gives rise to new questions. What are the problems with these kinds of tariffs from a customer point of view? In the interviews with the ten households in the load control study, time of use tariffs and tariffs like the one in the Sollentuna case were discussed. The ten household customers of Skånska Energi AB did not have any incitements in their tariff to save load. Most of these households said that they did not think about how much load they were using. In four of the households they were to a little extent concerned about the load level, because when they used too many appliances at the same time, the fuse broke. One of the households had a load guard in the electric heater. Sometimes when outdoor temperature level was low, this household had to be careful about how much load they used, otherwise the load guard would turn off the electric heater for a while which made it cold indoors. Therefore this household has adjusted their behaviour when it is cold outside.

Time tariff

The households were asked what they would do if the utility decided to introduce a time of use tariff (TOU) with a high and a low tariff for different time periods in the day. Half of the households said that they would adjust their energy use by shifting time for the use of some appliances.

There were two questions of particular interest that came up in the discussions about TOU:

- How large must the difference between the high and low tariff be in order to get the households to make some adjustments? Some households argued that here must be a significant incentive in changing the behaviour according to a tariff; otherwise the households would not think it is worthwhile.
- The other question was about price-elasticity and if the households' economic status plays a significant role for the affect that the tariff has on household electricity use. Although, there were some answers from the interviews that indicated that a higher economic status would make households less apt to follow tariffs, the sample is to small to make any general conclusions about this. This is however an interesting research question for future studies.

Tariff with load demand component

The interviewer described to the repondents how a tariff with a load component could work (like the tariff the that Sollentuna has), where some extent of the grid fee is based on the mean value of the three highest peaks in a month.

The households thought that this kind of tariff should be difficult to adjust to. How can the household keep track of when peak are occuring? Three methods are suggested that could help to prevent from high peak load:

1. That the household members learn how much load different appliances use and become cautious about not starting several appliances at the same time.
2. That the household install a load guard, that can help keeping a certain load level in the household.
3. That the household install a device or a meter, which can show the momentary load level in the household.

It was obvious that the households thought that they needed some help to control the load level. There were also some catches to the suggested methods. All household members can probably learn how much load different appliances use. But, as argued before, a lot of the electricity use is hidden, especially in houses with electric heating. In these households, one would also have to keep in mind the outdoor temperature. In households with many members it is more difficult to keep track of the use of load. In the interviews, some households also had thoughts about how other people, not living in the households, could contribute to power peaks if they were not aware of the tariff. A very important objection is that some households would have more trouble to avoid high coincidence load since they do not spend so much time at home.

To shift the use of certain appliances

As in the study by Levin & Wesslén (1993), the households' immediate ideas of possible activities to shift were the use of washing machines and dishwashers. The use of tumble dryers and drying cupboards could also be shifted in time. As could be seen in the in the ten highest peaks of the households in Figure 6, this kind of equipment really do contribute to high peak loads in the households. The households thought that they could postpone the use of these appliances to late evenings or nights. To postpone the use to times when there is none at home could be a risk for fire, as one of the households inflicted.

The two households that have saunas said that they could consider taking a sauna at low tariff times. Because saunas are by far the biggest installations when it comes to load demand, there would be a good idea to shift this load to low tariff times or to times when other appliances are not running. With technical solutions, for example with a heat storage tank, the households could turn off the heating at peak hours, but this is not something that most of the households came to think about.

Some persons are creature of habits. These persons form their everyday life according to repeatable patterns. In the energy diary study these patterns could be seen for some households but not for others. Persons with fixed habits are probably less flexible in shifting loads. One activity that practically all households did not want to shift in time was cooking.

This was the kind of activity the wanted to be able to perform "*when they needed to*". One household had some thoughts about baking and cooking large batches for refrigeration. These activities require some time and planning and are probably more rare in households with two full time careers.

In Paper V, a theoretical experiment was made. Starting from the highest peaks in the households during the diary period (in Figure 6), what would be the load savings if the load from the appliances, listed above, should be removed from the peaks? In Figure 9 the calculated saving from this analysis is shown.

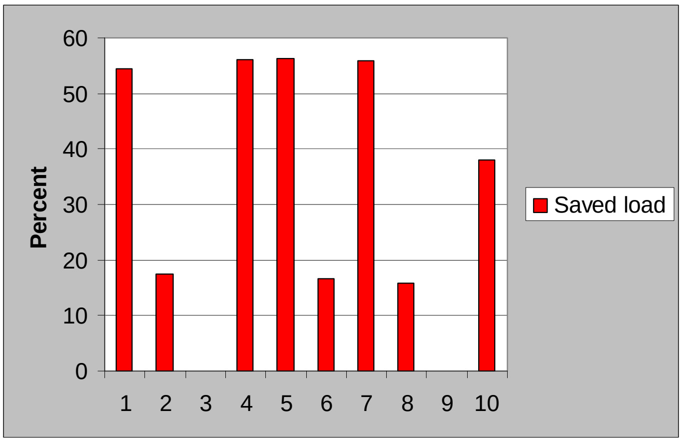

Figure 9: Load savings from shifting the load of certain appliances.

The calculated load savings ranged from 0% to 57% in the ten households (31% on the avarage). There is clearly a potential in indirect load managent. The problem is to develop pricing that seems attractive to the customer. In chapter 7.3.1 one successful model is described that was developed and tested within the Swedish research programme 'Market Design'.

7 Feedback and monitoring

Most dwellings in Sweden are equipped with electricity meter readers for individual metering, but not all households have their electricity meters easily accessible. The new law about monthly accurate billing for household customers comes in to force the 1 July 2009. This new law has already influenced electricity network companies to install new automatic remote meters (AMR) at their household customers. The AMR opens up to new possibilities using hourly data (or with even higher resolution) that now can be accessed by the companies. New energy services can be developed and offered to the customers. The question is: How will the companies make use of the new data?

7.1 Analysing load demand

In Paper VI, several established load analysis tools are analysed and discussed from the perspective of applicability, what kind of knowledge they could give and the strenghts and weaknesses the methods have. Hourly load data analysis can provide the detailed characteristics of load demand, define the consumption patterns and help to identify which households contribute most to the utility peaks. This information is essential when developing new energy services, pricing (as shown in Paper 2), load management strategies and demand response programs.

7.2 Billing and feedback

As shown in the results from several studies from billing based on actual use, there seems to be a potential for energy savings from this kind of billing. However, it is very hard to compare different studies, since the customers in the different studies are not exposed to the same kind of research settings and feedback.

Paper I examines customer preferences towards the electrcity bill. In this paper it is shown that there are different ways to read the electricity bill and that the cost of electricity in relation to the household budget is an important indicator of how carefully the customer read the bill, see Table 11.

Table11: The relation between high electricity costs and motivation to read the bill thoroughly.

The cost of electricity in relation to household budget	**Percentage of households that read the electricity bill carefully**	
	Yes	No
Very large part	65	34
Large part	63	37
Moderate	53	47
Small part	45	54
Very small part	41	59
Don’t know	41	58
Totally	53	46

Results showing that the feedback is more efficient when the energy cost stands for a larger part of the household budget is shown in earlier research, for example Constanzo with colleagues (1986).

The Swedish trade organization for the energy industry, Svensk Energi[44], emphasizes that there are different types of readers of the bill: those who just skim through the information on the bill, those who read the information to see if it is reasonable and those who check the reported meter readings against the electricity meter. Secondly, there are "inspectors", who control all the received information. Because "the inspectors" are the group who most often contacts the energy companies, the electricity bills have more or less been designed after their wishes. These are important findings to consider when using the bill as a feedback instrumet.

The electricity bill has several different symbolic meanings and areas of usage. In Table 12, different areas of usage are listed and organized in a company-customer perspective.

Table 12: Different areas of use of the electricity bills in a company-customer perspective.

Symbolic meaning and areas of use	**Electricity utility**	**Customer**
Invoice	To get payment for executed services.	To get information of costs and instructions of payment
Market document	An opportunity to present the company and to reinforce the company profile.	
Control tool		To be able to control if the cost of electricity is reasonable and if the reported use of energy corresponds with the electricity meter.
Feedback instrument	An opportunity to offer the service of feedback information to the customer	If interested, the customers can get valuable information on their energy use.

[44] Source: Svensk Energi. (2002). Vad gör elbranschen åt elräkningarna? http://www.svenskenergi.nu/nr12002/t-elrakning.htm., downloaded 2002-08-28.

In study 1 in Paper I, a little more than 1000 household customers from three Swedish utilities participated in a questionnaire study. In this study they had to answer to some statements on their attitudes towards the electricity bill, see Table 13.

Table 13: Statements concerning the electricity bill.

	Thinks it is impotant that the electricity bill is based on actual use		Read the electricity bill very thoroughly		More observant on the electricity use at home when the bill has come	
	Frequency	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Disagree	62	6%	139	14%	319	31%
Agree to some extent	105	10%	299	30%	239	24%
Agree to a high extent	196	19%	262	26%	203	20%
Fully agree	584	58%	247	24%	171	17%
Do not know	17	2%	5	0%	17	2%
No answer	49	5%	61	6%	64	6%
Total	1013	100%	1013	100%	1013	100%

Most of the households think it is important that the bill is based on actual use (73% fully agree or agree to a high extent). Somewhere about half of the households state that they read the electricity bills thoroughly, the other half does not. For some of the households the appearence of the electricity bill tends to influence their attention electricity use, but for the larger part this has no stated effect. This is interesting because if electricity bills can act as motivators for energy savings, they must first influence the households to pay attention to their energy behaviour.

In study 1 in Paper I, it was also indicated that many households found the electrcity bills difficult to understand, considering the many different parts that are accounted for on the bill. Specified information on the different parts gives the customers insight of what they are charged for. The way that the electricity is priced seem complicated to the customers. Three different types of charges are included in electricity bills: costs for electric energy (approximately 35 % of the total cost), distribution cost (about 20 % of the total costs) and governmental taxes and fees (i.e energy tax, electricity certificate fee and VAT – about 45 % of the total costs). A clear presentation is necessary to enhance comprehension of the bills. Yet, one may wonder if there actually is a particular need for customers to get specified price information on the energy bills, when products or services we buy from the store, are sold without specification of different types of costs that makes up the price. Take a banana, for example. We do not get any information of how much the costs for fertilising, watering, transport etc are. Nevertheless, all these costs contribute to the price (and to some environmental impact).

7.3 Customer preferences for various types of feedback information

In Study 1 in Paper 1, households were asked if they would like to get more specific information about their energy consumption on the electricity bill or via the internet. The share-out of answers is presented in the following list:

- **Warning:** Nearly 90 % of the households wanted to be alerted if the energy consumption suddenly increased.
- **Graph:** Around 75 % wanted a graphic presentation of the actual consumption compared with the consumption the same month the previous year.
- **Tips:** About 65 % wanted energy conservation tips incorporated into the bill.
- **Norm:** Just about 50 % wanted comparative statistical information from a comparable household.
- **Internet:** The least popular kind of information was statistical information via the Internet - 33 % were positive and 50 % negative. This should be put in relation to the fact that about 75 % of the households stated that they had access to the Internet at home or at work (64 % had access at home). So the accessibility was not solely the reason that the interest here was lower.

There seem to be large interest in getting feedback information on electrcity use. Graphic feedback information on the electricity bill seems to be more popular than obtaining simular statistics on the internet. In chapter 3.3, a study about a statistical service from Skånska Energi AB was mentioned. This service did not render in a very high user frequency, even if some customers today value this service highly according to utility representatives. Due to the time it takes to log in to the internet and the requirement of a certain level of computer skills, the paper bill is still a more accessable medium for many customers today. Sometimes, simple is beautiful! Another implication when using the electricity bill as a feedback instrument is the question of who actually reads the bill. Is it the one who gets the bill in his or her name? The one who pays the bill? Is the information or feedback shared with other household members?

The focus in this thesis has been more on how to get household customers to save load than to save energy (due to the focus on peak problems and load management). If the utilities want the houshold customers to pay for load demand, the electricity bill will not give sufficient feedback on this. For these customers other kinds of feedback instruments would serve the needs for controlling the momentary load in the household better. For example energy demand feedback devices for home use presented by Parker, Hoak and Cummings (see chapter 3.3).

7.3.1 On the development of feedback on energy use

McCalley and Middens criticism (mentioned in chapter 3.3) about the neglection of the underlying relationship between feedback and action in most energy feedback studies is an important criticism.

An interestesting approach has been taken on by the Swedish city of Växjö. In 2007, the municipality of Växjö was nominated “the greenest city in Europe”. In order to try to live up to this epithet, a campaign has been started (SAMS)[45] to get citizens of the city Växjö to save energy. An important element in this campaign is a new web-based service, EnergiKollen[46], where customers of the utility Växjö Energi can log in and check their electricity consumption. They can also compete with other households in the competition “SAMS-kampen” where persons or teams of customers can compete in how much energy that they can save. The motivational factors of participating in this type of contest will be interesting to follow in the future.

Another interesting project that has been carried out in Sweden, is a project within the research programme “Market Design”, with the aim to present and evaluate methods and business concepts to reduce electricity use in times of high spot price periods on the electricity market, at a national level (Lindskoug, 2005). One part of the project was to test the price sensitivity of household customers with different types of heating systems. For the experiment, a specific price list was designed where the electricity utility had the right to apply a higher electricity price during maximum 40 hours of a year. The remaining hours of that year, the customers were given a lower electricity price in comparison to normal prices at the utility. The higher electricity price ranged between 3-10 SEK[47] per kWh. The customers were informed about the (level of) higher price the day before via sms or e-mail. It was shown that the load at high-price times decreased drastically due to actions taken in the households to save load, in general a 50% decrease. Households with the possibility to shift from electricity to oil for heating did this shifting as soon as they got the message, whereby yet larger savings were achieved at cold periods. Even households without possibilities to shift heating source were shown to lower their electricity use significantly in high price periods. Results from interviews and questionnaires shown that the participating households generally had extensive willingness, ability and endurance to lower the electricity consumption during high price periods. The results from this study were repeated showing that the business concept can work as continuous business proposal to the customers. The results are actually rather remarkable since earlier studies have indicated that the price sensitivity is rather low.

Installation of AMR at the household customers will give the utilities the possibility to make use of hourly meterings and to provide feedback from this to their customers. But are hourly values of electricity of interest for the customers? And with what delay would this feedback be provided? The next day, they next week or the next month? Certainly, the frequency of feedback is an important factor for the customers to be able to connect the electricity use to certain activities.

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[45] SAMS is a project in cooperation with the housing companies Hyresbostäder i Växjö and Växjöhem, the energy utility Växjö Energi and Växjö municipality. SAMS is part of the EU-project Sesac. See http://www.vaxjo.se/vaxjo_templates/Page.aspx?id=6240, downloaded 11 May, 2008.

[46] See http://www.vaxjo.se/vaxjo_templates/Page.aspx?id=6257, downloaded 11 May 2008.

[47] 100 SEK corresponds to about 10,55 EUR.

In Paper V, there is a discussion of how different types of electricity use are connected to the activities in the household. From this perspective, different kinds of electricity use or functions could be categorised in the following way:

- Automatic controlled functions: Functions that are controlled by technical equipment such as timers, thermostats and sensors. Examples here are the electric heating system, freezers and refrigerators.
- Process-based functions: Functions where some fragmented efforts must be carried out by the user to start up a process, for example by the use of washing machines or dish washers, and to take care of the output, the clean laundry that needs to be hanged or moved to a tumble dryer or the clean dishes that need to be put in place in the kitchen cabinet.
- Activity-based functions: Vacuum cleaning, ironing, and using a computer.
- Lighting: this function is highly visible at one level, but it does not involve much activity from the user – just to turn it on and switch it off.
- Stand-by functions

By categorising the different functions of the electricity use in households in this way, it becomes rather clear that most of the electricity use within a household does not require much or any attention from the users. Moreover, all the different functions are aggregated in the measurement of hourly electricity use and, hence, it is very hard to interpret the feedback of hourly electricity use in terms of activities in the household.

I would like to argue that feedback on energy use would be more interesting for the users if it were translated to the value of money or to environmental impact. In order to estimate environmental impact, a primary energy use approach must be taken on, estimating the processes and losses from the ruption of natural resources all the way to the user, just like a life-cycle analysis. This is a service that consumers might very well ask for in the future, considering that they, for example, already take a great interest in green electricity and other types of “green” labelling (today, there are several different systems in Sweden that overlap each other). For feedback on primary energy use, the feedback from hourly meterings is not enough, since it only refers to the amount of energy used and not to the environmental impacts. An additional processing of this data should be carried out and other information should be added in order to accomplish these kinds of feedback.

8 District heating for single-family housing

8.1 Why expand in detached housing areas?

The expansion of district heating to detached house areas is a challenging task for the district-heating companies for two reasons: firstly, low heat density areas, such as detached house areas, are less profitable than expansions in more densed areas where the heat demand is higher. The second reason is that the selling of district heating to household customer requires different market strategies and sales processes than when dealing with professional buyers.

But, even if the expansions of district heating into detached housing areas are more problematic, there are nevertheless many reasons why these kinds of investments should be considered.

One obvious reason is that district heating in Sweden already has got the main part of the market shares on the heat market in other sectors. District heating is the most common form of space heating in apartment blocks (77%) and premises (59%) in the year of 2005 (The Swedish Energy Agency, 2007). For detached houses the situation is different. According to SCB (2007), only 9,4% of the energy sold for space heating came from district heating in 2006. This corresponds to a share of 7,3% of the Swedish houses that are equipped with district heating. Electricity still is the most used energy source for space heating in detached houses and approximately 40% of the Swedish one- and two dwelling buildings in 2006 have electricity or some kind of combination of electricity, bio fuel and oil. This means that there are large potentials for conversion to district heating in detached house areas, if district heating can be marketed as a competitive alternative.

Expansion of district heating is supported by Swedish energy policy, because it is viewed as an environmentally beneficial alternative compared to many other sources. In district heating production all kinds of fuel and heat can be used, and especially bio fuel, garbage incineration and waste heat are regarded as more environmental-friendly. The support from the government is showed in policy documents, energy plans and through different kinds of economic management control measures, i.e. energy taxes, climate investment programs and investment subsidies to households that wants to convert their heating systems from oil or electricity to district heating. The precondition of the investment subsidy is that district heating must account for at least 70% of the annual space-heating demand and for all the domestic hot water demand (Regeringskansliet, 2005). The investment subsidy makes the conversion to district heating a better deal for the customers and gives, at the same time, a hint to the customers that district heating is considered a better solution for the environment. In some cases conversion to district heating can lead to drastic local environmental improvements, for example in detached housing areas where small-scale wood-burning is effecting the air quality in the area.

Increasing prices of oil and electricity makes the investments in district heating more economically beneficial. The marginal of revenue for district heating can then grow due to the fuel flexibility in the district-heating production. Higher electricity prices also enable new investments in CHP-plants (combined Heat and Power plants), where the highly valued electricity can be sold at the Nordic spot market or exported to other European countries. However, to be able to use the heat from the new CHP-plants, the heat demand has to rise accordingly, and that is where the detached house sector can serve as a new heat demand.

8.2 The importance of a high connection rate

In district-heating systems, the heat is produced in large production sites, i.e. thermal power stations. This central, large-scale production of heat is more efficient in terms of the thermodynamic qualities (degree of efficiency), the environmental qualities (low emissions) and economic aspects (profit) compared to small and scattered heat production. Nevertheless, some of the efficiency in the heat production is lost when distributing the energy to end-users through pipes and networks. Investments in the distribution system are immense and the capital becomes frozen in the material assets. Together with continuous distribution losses for pump motor drive and heat losses, this means that large revenues from heat sales are needed (Persson & Sernhed, 2004). The fundamental requirement of a district-heating system is that the advantages of the centralised heat production should countervail the disadvantages that are associated with the cost for the heat distribution[48] (Persson, 2005). Figure 10 shows the relation between costs of local heat production compared with centralised heat production.

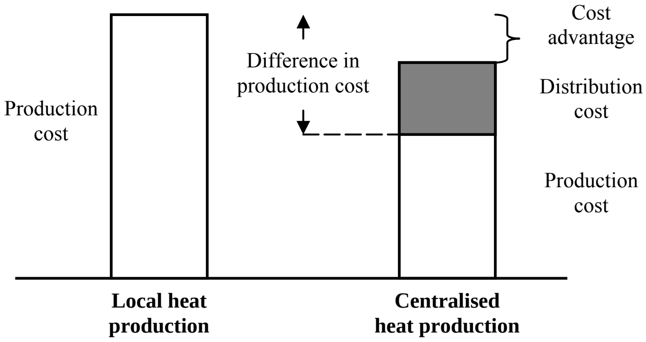

Figure 10: Difference in costs between local and centralised production of heat (Frederiksen & Werner, 1993).

To make a profit from district heating, the revenue must exceed the fixed and the variable costs for the heat distribution. The cost per produced kWh is dependent on the production plants, fuel costs, and taxes etc.).

Maximising the line heat density in the grid can lower the variable distribution costs in the grid (Persson & Sernhed, 2004). The line heat density is defined as the amount of heat energy sold during a year (Q_s), to buildings situated within a specific geographical area, divided by the total length of pipe pair - supply and return - (L), within the prospect area (Persson, 2005). Detached house areas generally have a low line heat density, between 0,4-1,5 MWh/m/year (ibid). This can be compared with the average line heat density in Swedish district-heating grids of 3,8 MWh/m/year (Werner, 1997). The line heat density (Q_s/L) can be enhanced by

48 In some cases, enviromental concern actually direct the investments of new district heating expansions where the profit is calculated to be low or zero. One example is where the community owns the district-heating grid and they want to solve the problems with emissions from wood burning in residential areas.

maximising the number of customers that connects to the grid. Because the distribution losses in low heat-density areas are relatively higher, the rate of connections is of great importance in these investments.

Low heat density areas are also challenging when it comes to fixed costs, here referred to as the investment costs for expansion of the grid and the equipment needed for customers to connect to the grid. Comparing the connection of 50 villas with the connection of a multifamily house with 50 flats, the detached houses need longer pipes (service pipes as well as distributing mains) and installation of individual district heating substations[49] in all the 50 houses, whereas only one substation is required in the multifamily house. Sandberg (2004) shows that the costs for connecting to the district-heating grid declines in proportion to the connection rate. This can be explained by the fact that the collective fixed costs can be shared between more customers.

This economic reasoning of variable and fixed costs of district heating expansions leads to one major conclusion: A connection rate is essential for the economy of district-heating expansions in detached house areas. The traditional focus on technical inprovements of better insulated pipes, cheaper ways of piping and restoring the ground and so on, is important for the economy in the business of expansions of district heating in low heat-density areas. Nevertheless, this focus must be supplemented by a new approach where the question of obtaining a high connection rate is emphasized. In doing this, customer attitudes, preferences, needs and decision-making processes must be considered and used in the development of new, improved sales strategies.

8.3 The urgency of expansion

A common motive for household customers to turn down the offer of district heating is that they recently invested in a new heating system (Henning & Lorenz, 2005). During the 1970s and the 1980s, there was a drastic infill of detached houses in Sweden[50]. Nearly half of all the detached houses built between 1971 and 2004 have electric heating as the only heating source, either waterborne or with direct resistive electric heating (SCB, 2005). According to a study by Mårtensson (2005), it was shown that detached houses built from 1975 and forward – when they were sold in the period of 1981-1995 – had electric heating as the only heating source in 75-80 % of the cases. Many of the households in these houses today own outmoded heating systems. For district heating companies, there is a window of opportunity to persuade households in these housing areas to adopt district heating as a new heating system. This window of opportunity will not be open for very long time though, because the need for changing the heating system must eventually be acted on by the residentials, sooner or later.

The competition from vendors of heat pumps also contributes to the pressuring urgency of expansions in detached housing areas. Heat pumps are popular today and the business is winning larger and larger market shares of the heat market for detached houses. Due to the need for a high rate of connections to the district-heating grid, the vendors of heat pumps can

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[49] In Swedish district heating systems the construction norm dictate the use of district heating substations. The substations contain a heat exchanger that separates the district heating system from the customer internal heating or domestic hot water systems.

[50] Source: Statistics Sweden (2006), *Nybyggnad av lägenheter i flerbostadshus resp. småhus*: www.scb.se., downloaded 2006-06-28.

puncture the market for district heating when they sell heat pumps in areas that are considered prospect areas for district heating.

8.4 District heating – Service or a product?

The provision of space heating and domestic hot water would probably best be described as a service. The peculiar characteristics of these services have been described in chapter 3.1 and 3.2, and these characteristics contribute to make the service of district heating fairly uninteresting and taken for granted after installed.

When district-heating companies offer district heating to house-owners, however, they are selling a heating system (or the possibility to connect to the grid) and not the heat itself. Heating systems have the characteristics of a product. This product – district heating as a heating system – is compared with other heating systems. Advantages and disadvantages of different heating systems are considered when households are in need of a new one, or when they are displeased with their incumbent systems.

8.4.1 Long-term investment

A heating system can be defined as an investment goods and not a consumer product, because it makes up for a sizeable cost at the time for the investment and because of the long lifetime of heating systems of, perhaps, 20 years or more. The timely need to change heating systems is hence an important issue in the sales strategies for district heating companies in particular, due to the need for high connection rates. Hallin, (1989) comes to the conclusion that households usually wait until their heating systems are nearly to break down or do break down, before they change the systems even if it would be more economic to change before. However, this shows that the timing of the district-heating offer is of great importance from a customer point of view, and hence it is an important parameter in the expansion strategies for district heating.

8.4.2 Differentiation of district heating

There is hard competition on the market for space-heating and domestic hot water preparation in detached houses. Along with the need or possibility to attract new customer, district-heating companies must also act according to the basic idea that district heating is a long-term, site-bound business and not let the reputation be jeopardized though short-term winnings. One strategy to compete on the market is through differentiation.

Kotler et.al (1996) define differentiation in following way:

> "Differentiated marketing: A market-coverage strategy in which a firm decided to target several market segments and design separate offers for each" (Kotler et al, 1996)

The prerequisite of a high connection rate implies an ambition to sell to all households within the same geographic area. Because it hence is impossible to segment customer groups, the challenge is to come up with flexible solutions that can work for as many as possible. Differentiation of the service district heating is hard in the same way as it is hard to differentiate petrol, for example. Instead of trying to change the very product of petrol, the franchisees try to differentiate their point-of-sales by adding additional services insteaed, such as selling hot dogs and a cup of coffee when customers stop to refuel the car, or to act as a convenience store with generous opening hours.

The way in which the Swedish industry of district heating has tried to differentiate the district heating services mainly referres to the development of different price models and, to a small extent, of additional services.

Wirén (2005) published one report about differentiation of district heating in detached houses focusing on price models. The aim of this report was to suggest different price models that would fit the villa customers' ideas of what would be appropriate connection fees and energy costs. The models are using different combinations or variations of three types of costs:

- **The connection fee:** in different models this varies from zero to full cover of the costs for the connections to the grid.
- **The cost for the district-heating substation**: This can etiher be subsidised or charged for. Management, maintainance and reinvestment can either be handled by the the district heating company or the customer
- **The energy price**: In subsidising the connection fee and the district heating substation, the district-heating company will then take out a higher energy price. Variations of variable or fixed contracts occur in different models.

Subsidizing the connection to the gird and the district heaing substation can be a strategy for district-heating companies to avoid the problem with "captive customers". If the customers only have to pay for the energy, they would not feel trapped in by high investment costs. As long as the energy price is lower than for alternative heat sources, this could be attractive to the customer. A fixed contract can protect the customer from price increases. Some customers worry that once they are connected to the district-heating grid, the company will raise the energy price.

Some additional services are mentioned in Mårtensson (2006): district cooling, snow melting, sequred energy supply in case of power shortages, energy surveying and saving tips. Some of these services emanate from the idea that new utilisation areas for heat could help magnifying the heat demand in the area. From a sustainability perspective, the enhanced comfort or convenience from new products or services should be analysed in terms of what social or economic winnings could be gained and what would be the negative environmental impacts. For example, in using district heating for melting the snow on pavements, accidents and bone fractures could be avoided. Hence, personal affliction, as well as social and medical costs, could be avoided.

8.5 Competitors

As argued above, when persuading households to connect to the district-heating grid, the district heating companies sell both a product (the heating system) and a service (the heat). This means that they actually compete on two markets: they compete with vendors of different kinds of heating systems (heat pumps, boilers and so on) and with other energy or heat producers (utilities of electricity or natural gas, suppliers of different kinds of fuels).

The vendors of heat pumps or boilers have an advantage compared to the district heating companies; they are not bound to keep their selling within a limited geographical area. They could sell ten heat pumps or boilers in one area and fifteen in another. For the district heating company that are dependent on a high rate of connections in one area, this is a disadvantage, since it can ruin the possibilities to get a reasonable heat demand in an area.

In competition with grid-bound alternatives like electricity and natural gas, electric utilities have the advantage that the customers already are connected or will be (in case of new housing estates), due to the fact that as good as all households in Sweden are connected to the electricity grid. Natural gas is not established more than in the southern parts of the country, but at those places natural gas can be used for heating purposes. Naural gas an electrcity have lower districbution losses than district heating.

8.6 Aspects of heating systems

Except from the disadvantages from grid-bound distribution, district-heating systems have many competitive advantages from a customer perspective. Households have to make up their mind about several different aspects when they choose among heating systems. The cognitions that people have are built on simplifications, or frames. This is necessary, because it is impossible to overlook all the relevant information or knowledge when making a decision (Klintman et al, 2003). Different aspects that customers often consider in choices of heating systems can be categorised in the following way:

- **Economic aspects**: Investment costs and energy price. From this information the households can estimate the payback time of a new investment.
- **Convenience**: Is the system automatized or does it require at lot of work or maintenance from the houseowner?
- **Comfort**: Thermal comfort and domestic hot water comfort differs between different kinds of heating systems. The space that the heating systems needs is also att matter of comfort, since large systems take up space that could have been used for something else. Odours and noices are present in some systems.
- **Aestetics**: Preferences on whether the system should be inbuilt or visible, influence the choice in some cases.
- **Environmental aspects:** Environmental impacts on the global, regional and local level, may play an important role in choices about heating systems.
- **Limited options:** all options of heating systems may not be available, at least not at reasonable costs.

In the interview study with households that had been offered to convert their direct resistive electric heating systems to district heating (Paper VII), the reasons why households accepted the offer were investigated. The different aspect listed above will be discussed from the result in this study. One must keep in mind that these households responded to a specific proposal from their district-heating supplier, and this will have some impact on the results. For a description of this propsal, see paper VII.

8.6.1 Economic aspects

For some households, economic aspects greatly influenced the choice to accept the offer. Three central aspects were emphasised by the households in the interviews:

- **Low investment costs.** The proposal was seen as very advantageous for the customers; the low costs for the installation of the new internal waterborne heating system, in particular.
- **Expectations of lower energy bills.** The energy price for district heating in Växjö was rather low compared to prices of other district heating companies. It was also significantly lower than the electricity price. This made district heating more attractive for the households in terms of operating costs. It was supprisingly few households that new about the atual savings they had made since they shifted from electricity to district heating. The short payback time and the sunken costs for the households are good marketing arguments for the district-heating companies. The savings should be better communicated to enhance customer satisfaction at households that have shifted to district heating, empasizing the long-term customer relations.
- **Expectations of increased value of the real estate.** If the value of the real estate is increased by the conversion, the deal is a low-risk decision since the houshold will eventually get the money back when selling the house.

8.6.2 Comfort

When the interviews took place, almost four years had elapsed from the time of conversion. This means that the households had plenty of time to evaluate the function of their new heating- and hot water systems.

Since the households used to have direct resistive electric heating, they experienced an improvement of the thermal comfort in the houses after the conversion to district heating. This positive change was actually not due to the change electricity to district heating, but to the internal waterborne heating system that was installed in order to be able to use hot water as an energy carrier. The households stated that the air humidity was improved after this installation and that they got rid of the smell from burnt up dust and the inconvenience of electric wall heaters that could become very hot.

Some households experienced that the domestic hot water comfort actually deteriorated. After conversion, it took longer time to get hot water from the tap and in summertime there could be some troubles of obtaining high temperatures. In district-heating systems, domestic hot water comfort can be problematic since the pattern of hot water usage is erratic and variates much more than the heat load and this put more strain on the district-heating substation. In detached houses the use of domestic hot water can be very sporadic because there are not so many users (Persson, 2005). There are, however technical solutions to these problems and this can be an important factor to work with for district heating companies, in order to enhance customer satisfaction.

8.6.3 Convenience

The use of district heating for space heating and domestic hot water provision is relatively manitenance-free. In the offer from Växjö Energi, all parts of the conversion to district heating were inclusive: the connection to the grid, the convertion of the indoor heating system and the district-heating substation. For the households, this was viewed as a convenient way to shift the old electric water heaters and all the old radiators in the house at the same time.

8.6.4 Aestetics

Direct restitive electric heating systems do not require any pipes. For some households, it was actually an issue that the new system would require pipes on the wall. Would the pipes on the wall look ugly? The district heating company used one of the customers' houses as an exhibition object to show the other customers how the installation of the internal waterborne heating system would look like. Alhough, this was a very good idea, the installation in the exhibition house was not very beautifully made, which caused a lot of reactions from the neighbouring households. The misstakes made in this first house were adjusted in later installations, but the damage was already done, because it discouraged some households to accept the offer of district heating. However, even if the pipes really became an issue in the beginning, most households that installed the system, said that they forgot all about the pipes after some weeks.

8.6.5 Environmental aspects

The environmental argument does not seem to have been the downer for the acceptance of the district-heating proposal. Environmental arguments are however, still important, and are regarded as a bonus that makes the proposal more attractive. In interviews it was shown that some households understood the benefits from incineration in large-scale district heating plants and some households were concerned about the environmental impacts of their energy use, althought they did not care to look into what kinds of fuels that were used in the production mix of their district heating plant. The simplification that *"district heating is an environmental good alternative for heating"* was enough for these customers.

8.6.6 Limited options

Households that have direct resistive electric heating only have a limited selection of heating systems to choose from if they want to shift heating system. This is because they must first change their internal heating system to a waterborne one, to be able to use most other alternatives (i.e. boilers or heat pumps other than air-to-air heat pumps), and for a single household this installation can be costly. Växjö Energi could make this installation at much better prices, using a contract by tender for many customers at the same time.

Since the houses with direct resistive electric heating are built for this type of heating system, they have no chimneys and not much space to put a boiler in. This is limiting the options that these households can chose from.

8.7 Potential customers

Different households in a housing area cannot be considered a homogeneous group (even if there sometimes can be concentrations of specific demographical factors in neighbourhoods). The households differ in size, composition, age, income, education, and occupation. Since the district heating companies are so dependent on getting a high connection rate, one would think that they would make extensive efforts to collect information about their potential customers in strategic areas. Results from the questionnaire study in Paper III show that this is not the case.

The study investigated how the district heating companies gather information, what kind of sources they use and what kind of information they collect. In Figure 11, results from the survey regarding which sources district heating companies use to obtain information about the potential customers are put together.

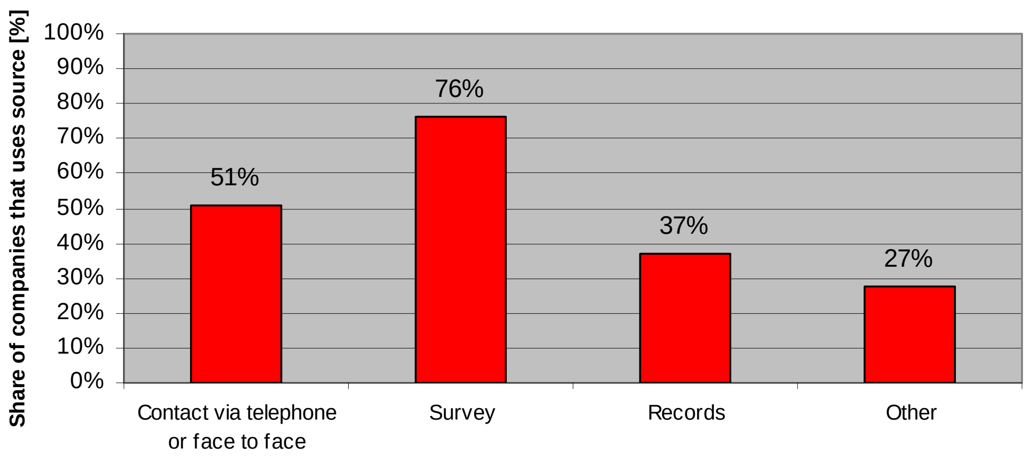

Figure 11: Sources of customer information used by district heating companies.

Surveys seem to be a common way to gather information about customers and therefore, it is rather remarkable that the companies do not use this opportunity to gather information about the social factors of the potential customers, see Figure 12. (The results shown in Figure 11 are further discussed in Paper 3.)

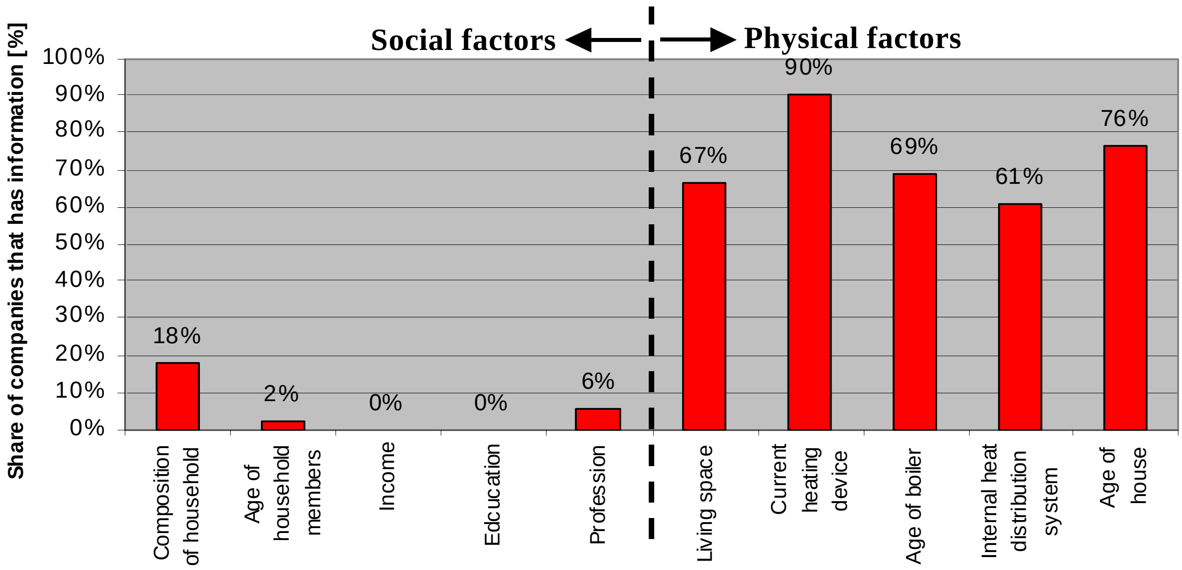

Figure 12: Facts about potential customers.

The physical factors are important when investigating the potential heat demand that could be achieved if the households would connect to the district-heating grid. They also give important indications of the need for change of heating system in the area. If the incumbent heating systems in the households are old, the households have a need for changing their heating systems and the offer of district heating might be regarded as opportune. However, the district-heating companies do not investigate the social factors. Does this imply that the Swedish district heating companies to some extent still consider their customers mainly as subscribers for heat rather than customers with different preferences and needs?

But what would be the benefits from gathering information about the potential customers social conditions?

In the study (in Paper VII) of households choices of accepting or rejecting an offer to adopt district heating, it was shown that age and type of household were variables that affected the choice of district heating in this housing area. In an analysis of the mean value of the variable age, it was shown that the mean value for households that did not convert to district heating was higher than in households that did convert: 59.5 years compared to 52.2 years. For older households in the study, there were both households that accepted the offer of district heating and households that did not. For the younger age group, all the households from 40 years and younger had converted to district heating. Thus, younger households seem to be more prone to choose district heating. In Figure 13, converted and not converted households are categorised in different household types.

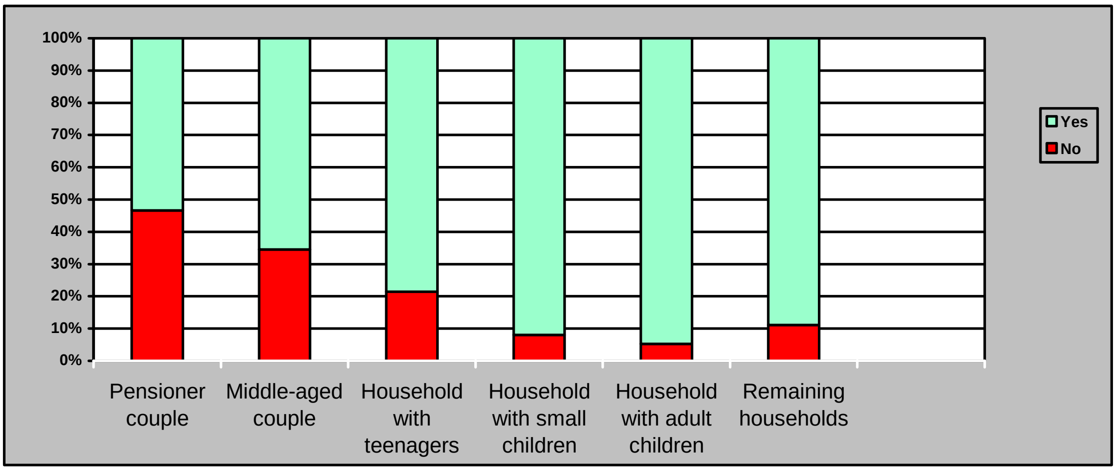

Figure 13: Share of households, divided in household types, which has converted to district heating.

As shown in Figure 13, the pensioner couples have been least apt to accept the offer of district heating. This corresponds well with the variable of age as an explanatory factor. Nine out of 16 households in this group did accept the offer, which is a little more than half of these households. In the group with middle-aged couples the share is higher: 19 out of 29 accepted the offer (65.5%). In the households with small children, 16 out of 17 of the households accepted the offer (94.1%). Because these families are mainly the same as the younger households, this result was expected. A somewhat more unexpected result was that, in the group of households with adult children, only 1 out of 19 turned down the offer. This is noteworthy, because the parents in these households are in the same age as the middle-aged couple households, which were not so prone to accept the offer of district heating. Therefore it seems to matter to the decision of connecting to the district-heating grid whether the children move out or stays in the household.

Then, what is it that makes younger households accepting the offer of district heating? The interviews did not give an unequivocal answer to this question, nevertheless there were some interesting facts that can be interesting to discuss.

In the interviews, many of the younger households told that they became interested in the offer immediately when they got the information about it. Consequently, one could say that they had a positive image of district heating already from the start. This could be explained by the fact that several of these households rather recently moved in to their houses and that they, before this, often lived in flats with district heating with pipes placed on the walls. Many of these households have no experience to handle a pellet-boiler or oil-boiler, and district heating might seem like an attractive way to heat the house with. Certainly, the electricity systems that were installed in these houses, did not demand mush management either, but when the district heating offer came they saw their chance to change the old system and to improve the indoor comfort at the same time.

As argued before, adult children still living with parents also gave rise to a higher rate of connections. What can be the explanation for this? Maybe it could have something to do with a higher demand for energy and that the parents thought it was worthwhile to change to district heating because of this? The utility assisted with data on the electricity use for the households the year before they converted to district heating, that is the electricity for heating, hot water and domestic electricity use together. In an analysis of the mean value of the electricity use for the different household types, it was shown that the households with adult children still living at home in 2005, had higher electricity use than the middle-aged couples without children staying at home: 20,334 kWh compared to 18,172 kWh. However, the cause for this reslut not easy to interpret.

Age and household type was seen to have some explanatory value to which households are more willing to accept the offer of district heating. To make a general conclusion about this, more areas should be tested first. However, there are reasons to believe that these social factors can be influential. Therefore, the district heating companies could benefit from collecting information about these social factors for their potential customers.

Consequently, a new focus of social facts about customers must be taken on to improve the sales strategies in district heating companies. By doing this, the companies have to consider that household customers are not a homogeneous group, and that selling district heating to households in detached house areas requires different market strategies and organisation of the selling than the selling to professional buyers in real estate concerns.

8.7.1 Why some customers say ‘no’ to district heating

In the results from the interviews in Paper VII, the following reasons were shown of why some of these households had turned down the offer to convert to district heating:

1. The household had already made reinvestments in the old heating system (changed the radiators and/or the electric water heater).

2. The household had installed a secondary heating system. Some households had invested in air-to-air heat pumps and some had installed tile stoves or the like. These households often had access to cheap fuel wood.

3. The household had some objections to the aesthetic aspects of the district heating installation (mainly about the piping).

4. The household thought the conversion would be inconvenient and they did not know what the consequences from the digging or the installation of the internal waterborne system would be, and what was required in terms of own efforts.

5. Misunderstandings. The household was given incorrect information, or the customer misinterpreted parts of the district-heating proposal.

Then, the question is: What can the district-heating companies do to decrease the impacts from these factors? This will be discussed in the following subchapters: 8.8.1 and 8.8.2.

8.8 Some improvments of marketing strategies

District heating in low heat density areas is a research area within the Swedish District Heating Associations research programme “Värmegles”. Within this programme, a number of different reports have been published that focus on making the expansion of district heating in low heat density areas more profitable. The attention has mainly been directed to find technical solutions that could help lowering the construction costs, for example the use of cheaper and more long-lasting materials, to find cost efficient solutions of piping and restoration of the ground and to decrease heat losses in the pipes by the use of better insulation. A few studies have actually touched on the questions of selling and marketing district heating to households in detached houses. A special emphasize has been on the development of different price models to attract customers with different economic prerequisites. Thereto, the development of price models with a low investment cost for the customer have helped diminishing the sense of look-in that is often experienced by customers in local monopolies and were high investments in equipment are required for the customers to be able to connect to the system.

A favourable energy price is emphasized by the Swedish district-heating industry as one of the critical reasons to why household customers choose a certain heating system. Therefore, the energy price is an important subject to work with when developing new marketing strategies. But, the traditional neo classical view that is taken on by looking only at economic aspects of the customer buying-decisions, viewing the customers as economic rational decision-makers, can be criticized. The critique of this rationality lies within the difficulty for the decision maker to obtain all the relevant and accurate information needed to be able to make a (economically) rational decision (Costanzo et al, 1986). The marketing of district heating should also be dealing with other forms of marketing strategies that aim to look at the household customers as social beings in a social context. Only a few studies have been focusing on this (see for example Henning & Lorenz, 2005; Mahapatra, 2007: Mahapatra & Gustafsson, 2008).

In the next subchapters, there will be a presentation of some of the findings in Paper III and VII, where the list in the previous chapter (Chapter 8.7.1) may serve as a checklist for issues that the district heating companies should consider in order to achieve a higher rate of connections.

8.8.1 The problem of timing

When a new district-heating grid is being built, some customers might not have the interest or means to get connected. For example, they might have just invested in a new heating system or they don't have the money to put in to the investment at the present time. Some of the district heating companies in the study of Paper III came up with strategies to deal with timing problems when converting the customer heating systems:

- **Customer compensation for current heating device:** Some companies pay for the customers' old equipment in order to attract those customers who recently invested in a new heating system. The compensation is often restricted to an age limit of the equipment.
- **'Heat emergency':** Sometimes customers have problems with their old boiler before the district-heating grid has been fully constructed and they can connect to it. To help the customer – who has already signed the contract with the district heating company and therefore is not interested in another new system – the company can offer to install a heating system to operate until the connection can be made. Some companies use old boilers they have bought from other new customers. A few companies have come up with the solution to install the district-heating substation that will be used, but to use it temporarily with an immersion heater. The cost for the heat during this temporary solution sometimes is adjusted to district heating prices.
- **Mediation of boilers:** Another example to facilitate customer change of heating system is to help mediate old boilers to other buyers.
- **'Resting connection':** If the customer for some reason don't want to connect to the district heating grid, pipes are drawn to the customer facility, even if the customer does not buy heat. Different companies have different agreements on time limitations and connection fees. In some interviews there has been companies that strongly oppose the use of resting connections due to problems that occur when the customers choose never to connect to the grid.
- **Repurchase of oil:** Some examples exist of companies that offer to purchase the remaining oil in the customer boiler tank. This offer could of course be extended to include other types of fuel.
- **Competitive pricing:** Some companies choose to subsidize the connection fee in order to make the financial part easier for the customers. In this way, customers with small possibilities to take out mortgages on the house or that suffer from a temporarily bad economy, still can afford to make the connection to the district-heating grid. If the energy price for district heating is considered to be substantially lower than for other alternatives, this also can have an impact on the household's immediate living expenses.

Moreover, anticipant planning of expansions of district heating in new areas can also help the households in prospect areas to plan for future investments in the heating system. In the interview study it was shown that some of the households that rejected the proposal of district heating for the reason that they already made some other investments recently, actually would have accepted the district-heating proposal if they would have known in advance that district heating was going to be an option. Therefore it is better if the district heating company can reveal their plans of expansions in good time to customers in the prospect areas.

8.8.2 Personal selling

In the study of Swedish district heating companies' expansion strategies in detached house areas (Paper III), it was shown that most of the companies tried to manage the selling of district heating to household customers within the existing organizational structures. This is a common strategy within monopoly conditions, according to Markard & Truffer, discussed in Chapter 2. The Swedish district heating companies do not want to spend too much time and resources on the selling and hence, personal selling is often viewed as a too costly method to attract customers. But the misunderstandings and worries that some of the households had (in Paper VII) could have been straightened out and discussed if personal contacts would have been taken with households that did come forward in the interest inquiry.

9 Discussion

The focus in this thesis has been on customer relations between electricity and district heating utilities and household customers in Sweden, with and emphasize on customer needs, attitudes, preferences and acceptance towards company proposals within three particular fields: *Electricity peak load problems and load management in households*; *Energy monitoring and feedback*, and, *The marketing of district heating to households in detached house areas.*

The interest in these fields comes from two directions. Firstly, learning about customer needs, attitudes, preferences and acceptance are important factors for energy utilities for the profit making, and for being competitive on the market. Secondly, sustainability in the development of energy supply and use is demanded from a policy level at the EU level and the national level. Different regulations and control management measures are developed and used to influence the energy business in a sustainable direction. In order to enhance this development, the interaction between energy utilities and their users are important, because this can lead new solutions on the demand-side or in the introduction of innovative technology at the household customers. An increased focus on environmental impacts from energy use, such as the question of climate change, the acidification of lakes, eutrofication, health problems and biodiversity, also makes citizens more concerned about their energy use and how the energy that they are using is produced. This customer interest leads to the need for new development of products and services for the energy companies.

The perspective of sustainability presupposes interdisciplinary research. This is rather evident since sustainability means taking economic, social and environmental aspects into concern. The approach in the studies in this thesis has been to cover all these three areas placed within the technical possibilities of the large technical systems that have been emphasized, namely electricity systems and district heating systems.

There will always be a need for research about customer attitudes, needs, preferences and acceptance. This is because these parameters are changeable and dependent on different factors in the natural and social world. What is considered as urgent today may not be considered vital tomorrow. Therefore, it is important to develop methods to investigate these factors to be able to analyse the changes.

It is the hope that this thesis has made a useful contribution to this knowledge development, not least to a pluralistic *methodological* outlook. Many customer researches that are conducted today use questionnaire surveys as a method, because it is a fairly cheap and effective method to gather a lot of information. These surveys, however, seldom give the elbowroom to state the question of *why* people think or act the way they do. The *combination* of methods used in this thesis has been chosen in order to find the causal relationships between variables and matters, which would be difficult to examine using single, isolated methods.

For sure, research is a search for answers. Still, the new questions that emerge are often as important as the (preliminary) answers that the research delivers. In this thesis, several new questions have emerged.

The results from the field *Electricity peak load problems and load management in household*, indicates that there are several concerns that have to be made when introducing direct and indirect load management to household customers. The measures should be developed in that way that they pay regard to customer comfort and convenience. Yet, it is shown that costumer comfort and convenience are actually up for negotiation, as long as there are incentives for the customers that can compensate the loss of comfort and convenience.

An important research question for future research within this field is how national peak problems can be solved through demand-side management, when the customer relations occur at a local level. The incentives to load management for local utilities are often economic ones, dependent on the contracts that these actors have with actors at the regional level. For national peak problems there are many intermediaries. How do the different contracts and regulation on different levels in the electricity system affect the possibilities for solutions on the demand-side?

New installations of AMR at household customers will give new possibilities for the Swedish electricity utilities to use the data will be available through the new meters. Some of the studies in this thesis give examples and suggests methods of how this data can be used and applied by the utilities for different purposes: for analysing load patterns, for developing new tariffs, for customer segmentation, and for designing feedback services to their customers. The feedback to customers must be developed with the customers' needs, preferences and prerequisites in mind. The questions of what motives do the customers have for using the feedback and what motivates the customers to take action to conserve energy must be considered. With the increased attention to environmental impacts of our energy use, customers today and in the future will probably be more interested in feedback that relates their consumption to this. Hence, the data for hourly metering must be processed in order to give this information. Psychological questions of cognition and motivation of how feedback works best for different persons is an important field for future research. Studies that will follow the development of the use of new services from the Swedish electricity utilities are also of importance, as well as technical solutions on how to handle the large quantities of data that comes from the automatic meter reading.

Using district heating in residential detached housing areas can be an environmentally good solution, even if it is impaired with higher heat losses compared to district heating in areas with higher line heat density. A high connection rate is a vital part of the economic prerequisites for district heating expansions in these areas. Therefore, the traditional technical approach that many district-heating companies in Sweden have today, must be supplemented by sociological research of customer needs, decision-making and preferences. The district-heating companies must put more emphasis on social factors in their marketing of district heating to homeowners in detached houses. The results from the studies in this thesis indicate that the life cycle of households play a great part for the planning of housing, where the heating-system is an essential component, because it greatly influences everyday life in households in terms of comfort and convenience. Although there are many more questions to answer on the customer side, it would also be interesting to focus on the decision-making of district-heating companies in future research. Why are some of the companies very active in the expansions to detached house areas and others are not? What factors are influencing the companies to expand to the detached house sector? Is it the ownership of the company, the organisational culture or 'balls of fire' within the organisation that makes things happen? Or, maybe, is it the physical factors, such as access to cheap heat or geographical beneficial conditions that decide how active the district heating companies are in expansions to detached housing areas? Even if some of these questions were answered in this thesis, a qualitative approach to these questions would probably give more insight to the research problems.

10 Summary of publications

10.1 Publications included in this thesis

Paper I: Sernhed, Kerstin., Pyrko, Jurek., Abaravicius, Juozas. *Bill me this way! - Customer Preferences Regarding Electricity Bills in Sweden,* ECEEE Summer Study, St Rafael, France, June 2003.

The aim of this paper was to examine household customers preferences regarding their electricity bill, presenting two major customer surveys carried out in 2002 that concentrated on Swedish households' requirements concerning their electricity bills. The interest in energy management lies within the fact that the electricity bill can be used as a feedback instrument to influence energy behaviour and the consumer's awareness of energy usage. The paper covers questions like: What kind of information do households want on their bills? What information or which services should be included on the bill regarding content, design, medium and frequency? How important is it whether the bill is based on actual readings of electricity use and not just on preliminary estimates? The experience of Swedish households indicates that the information included in the electricity bill is difficult to understand. Most customers feel that it is important that the bill is based on current readings of electricity usage. The electricity bills are not coming frequently enough to enable the households to relate their usage of electricity to habits and behaviour in everyday life. Historical information on the household's electricity usage could be added to the information in the bill to make such relations between electricity consumption and habits visible, although there are some limitations due to the format of the bills. The cost of the feedback is also an obstacle since neither the sender of the bill nor the receiver is willing to pay for the information.

The author of this thesis made the analysis and wrote the article. The co-authors helped with the general analysis. The article is to a large extent based on a survey carried out by Jurek Pyrko, Peter Matsson and the author of this thesis.

Paper II: Pyrko Jurek., Sernhed Kerstin., Abaravicius Juozas., Pérez Mies Victoriano., *Pay for Load Demand. Electricity Pricing with Load Demand Component*, ECEEE Summer Study 2003 Proceedings, Côte d'Azur, France.

A possible way to lower peak loads, avoid electricity shortages and reduce electricity costs both for users and utilities, is to make customers experience the price difference during peak load periods and, in this way, become more aware of load demand. This paper investigated the Swedish energy utility Sollentuna Energy AB's new electricity tariff with differentiated grid fees based on a mean value of the peak load every month. The objective of this study was to investigate the extent to which a Load Demand Component, included in electricity pricing, could influence energy use and load demand in residential buildings. What were the benefits and disadvantages for customers and utilities? This paper investigated the impact of the new tariff on the utility and on different types of typical residential customers, making comparisons with previous tariff.

The author of this thesis contributed to the discussion and the analysis of the results, but was not involved in data collection or the computation of the data. Master student Victoriano Perez Mies executed most of the work in the underlying study under supervision of Jurek Pyrko that was the one who coordinated the publication.

Paper III: Sernhed, Kerstin., Abaravicius, Juozas., Persson, Tommy., *District Heating Expansion Strategies in Detached House Areas*, 9th International Symposium on District Heating and Cooling, Espoo, Finland, 2004. Published in EuroHeat&Power, English ed. Vol. 4, pp. 22-24, 2004.

The objective of this study was to find out what kinds of sales strategies Swedish district heating companies have for expansion into low heat density areas. To investigate this topic, a survey was sent out to all DH companies in Sweden. The questionnaires were followed up by telephone interviews. The study concludes that the most important factor when DH companies are choosing a new expansion area is the close location to the existing network. Furthermore, the information collected by the companies about their potential customers indicated that the customer is to a great extent seen as a "heat load" in the system rather than an individual with different needs and interests. Promotion campaigns in detached housing areas often include the phenomenon of social diffusion, where the companies use interested potential customers to promote DH. Specific sales strategies have been developed by the companies in order to solve timing problems that arise when the potential customers replace their existing heating source with DH. Value-added services are rare in the DH field.

All three authors contributed to the gathering and analysis of information, and to the writing of the paper. The author of this thesis was appointed first author of the article since her contribution to the project had been greatest.

Paper IV: Abaravicius, Juozas., Sernhed, Kerstin., Pyrko, Jurek. *Turn Me On, Turn Me Off! Techno-Economic, Environmental and Social Aspects of Direct Load Management in Residential Houses*, ECEEE 2005 Summer Study, Mandelieu, France May 30-June 4, 2005.

The aim of this study was to experimentally test and analyse direct load management in 10 electric-heated houses from both customer and utility point of view. The houses were equipped with extra meters, enabling hourly load measurements for heating, hot water and total electricity use. Household heating and hot water systems were controlled by the utility using an existing remote reading system. The residents were informed about the experiment but not about the time and duration of the controls. The experiment was followed up by interviews. According to the interviews, the residents noticed some of the control periods of heating. Body activity level as well as compensation of sun radiation and heat producing appliances influenced the experiences of indoor climate comfort. After the experiments, the households were positive about load control measures, but with some considerations of the control periods.

The author contributed to the planning and implementation of the load control experiment, and carried out the interviews and meetings with the households. Juozas Abaravicius was the main author of the article and coordinated this publication. Jurek Pyrko was the project leader and contributed to the general analysis of this paper.

Paper V: Sernhed, Kerstin. *What's on the top?* Energy Efficiency in Domestic Appliances and Lighting (EEDAL) conference Proceedings, London, UK, June 21-23, 2006.

Most energy behaviour studies on households focus on the questions *how* and *why* we use energy and what can be done to lower energy consumption. Very few studies raise the question of *when* energy is used or examine the underlying explanations to load patterns. Which is of great interest when trying to solve technical and economic problems with electricity peak loads. This paper emphasizes these questions through a case study of ten households with electric space heating in southern Sweden. In these ten households, electricity use for heating, domestic hot water and appliances were measured as three partial loads with five minutes resolution. Energy diaries were kept by the household members and the combination of these two sets of data made it possible to see what appliances were used and what activities were carried out during power peaks.

Paper VI: Abaravicius, Juozas., Sernhed, Kerstin., & Pyrko, Jurek., *More or Less about Data - Analyzing Load Demand in Residential Houses*, ACEEE 2006 Summer Study Proceedings, Pacific Grove, California, USA, August 13-18, 2006.

This study aims to discuss the possibilities and the benefits of using interval (hourly) metering data from residential consumers. Through the analysis of strengths and weaknesses of different load analysis tools, this paper defines the knowledge they could give, how applicable they are and what value they could have both for the utility and for the residential customer. The study is exemplified with ten cases of households with electric space heating in Southern Sweden.

The author of this thesis contributed to the novel idea of the content in the paper and helped with the structure and analysis. Juozas Abaravicius was the main researcher and was responsible for writing the publication. Jurek Pyrko contributed to the general analysis of the paper.

Paper VII: Sernhed, Kerstin. & Pyrko, Jurek., *Make the heat hotter! Marketing district heating to households in detached houses.* The draft paper is accepted at the 11th International Symposium on District Heating and Cooling, Reykjavik, Iceland, 2008.

This paper investigates a case of one Swedish district heating company's marketing activities and expansion strategies in a detached house area where the customers were offered conversion of their direct resistive electric heating into district heating. Eighty-eight out of 111 houses were converted in 2002. Four years later, interviews were carried out with 23 of the households in the area, both with those who accepted the district heating offer and those who didn't. The study shows that besides the economic aspects, also thermal comfort, aesthetics and practicalities effected the buying decision. Since the different economic aspects of the offer were complex to comprehend, it was very hard for the households to be strictly economically rational. Statistical analysis proved that variables such as age, type of household and energy use level could, to some extent, be related to the decision to convert from electric heating to district heating. Timing, low prices and total solutions presented for the households were crucial factors in the marketing strategy.

The author of this thesis carried out most of the planning and the implementation of the study. Jurek Pyrko participated in the implementation by doing some of the interviews and contributed to the general analysis of the study.

10.2 Other publications by the author

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Appendix A

DIRECTIVE 2006/32/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
Of 5 April 2006
On energy end-use and energy services and repealing Council Directive 93/76/EEC

Article 13

Metering and informative billing of energy consumption

1. Member States shall ensure that, in so far as it is technically possible, financially reasonable and proportionate in relation to the potential energy savings, final customers for electricity, natural gas, district heating and/or cooling and domestic hot water are provided with competitively priced individual meters that accurately reflect the final customer's actual energy consumption and that provide information on actual time of use.

When an existing meter is replaced, such competitively priced individual meters shall always be provided, unless this is technically impossible or not cost-effective in relation to the estimated potential savings in the long term. When a new connection is made in a new building or a building undergoes major renovations, as set out in Directive 2002/91/EC, such competitively priced individual meters shall always be provided.

2. Member States shall ensure that, where appropriate, billing performed by energy distributors, distribution system operators and retail energy sales companies is based on actual energy consumption, and is presented in clear and understandable terms. Appropriate information shall be made available with the bill to provide final customers with a comprehensive account of current energy costs. Billing on the basis of actual consumption shall be performed frequently enough to enable customers to regulate their own energy consumption.

3. Member States shall ensure that, where appropriate, the following information is made available to final customers in clear and understandable terms by energy distributors, distribution system operators or retail energy sales companies in or with their bills, contracts, transactions, and/or receipts at distribution stations:

(a) current actual prices and actual consumption of energy;

(b) comparisons of the final customer's current energy consumption with consumption for the same period in the previous year, preferably in graphic form;

(c) wherever possible and useful, comparisons with an average normalised or benchmarked user of energy in the same user category;

(d) contact information for consumers' organisations, energy agencies or similar bodies, including website addresses, from which information may be obtained on available energy efficiency improvement measures, comparative end-user profiles and/or objective technical specifications for energy-using equipment

Appendix B

Household		H1	H2	H3	H4	H5	H6	H7	H8	H9	H10
Occupants	**Gender and age**	1M26-65, 1F 26-65	1F 26-65, 1M 26-65	1M 26-65	1M 65+, 1F 65+	1F 26-65, 1M 26-65	1F 26-65, 1M 26-65	1M 19-25, 1F 26-65, 1M 26-65	1M 13-19, 1M26-65, 1F 26-65	1M 33, 1F 32, 1baby	1M 45, 1F 44 (1F 16, 1M13 half time)
	Home during daytime?	sometimes	yes (M)	yes	yes	no	no	sometimes	no	yes	no
	Annual electricity use (2003)	20993 kWh	27597 kWh	21254 kWh	21626 kWh	22950 kWh	16528 kWh	15396 kWh	17272 kWh	14019 kWh	18478 kWh
House	**Type**	detached	detached	detached	detached	detached	semi-detached	semi-detached	semi-detached	detached	detached
	Levels	1,5 stories	1 storey	1 storey	1 storey	1 storey + basement	2 storey	2 storey	2 storey	1 storey	1 storey
	Living area	160 m^2	186 m^2	180m^2	145m^2	150m^2 + 150m^2 basement	118 m^2	118 m^2	110 m^2	116 m^2	95 m^2
	Construction year	1968	1951-75	1965	1964	1974	1978	1978	1978	1969	1969
	Construction type	brick with wooden frame	brick with light concrete frame, (60m^2 brick and wood frame)	brick with light concrete frame	brick with light concrete frame, (55m^2 brick and wood frame)	brick with wooden frame	brick with wooden frame	brick with wooden frame	brick with wooden frame		
	Glazing	triple	triple	triple	triple	double and triple	double	triple	triple	double	triple
	Fuse level	20A	20A	20A	16 A (load guard)	20A	16A	16A	16A	20A	20A
Heating system	**Type**	waterborne, electric furnace	waterborne, electric furnace	waterborne, electric furnace	waterborne, electric furnace	direct resistive, electric radiators	direct resistive, electric radiators (oil-filled)	direct resistive, electric radiators	direct resistive, electric radiators	direct resistive, electric radiators	direct resistive, electric radiators (oil-filled)
	Power	13kW	13,5 kW (steps 2,5;4,5;9kW)	13 kW	15,75 kW (9kW limited)	11,4kW + 8,7kW in the basement				8,3 kW	6,5 kW
	Control system	outdoor sensor	outdoor sensor, thermostats	outdoor sensor, thermostats on radiators (not all)	outdoor sensor, thermostats on radiators	thermostats on radiators	"Soft heating" with outdoor sensor, temp. limiter		"Soft heating", temperature sensors in rooms	thermostats on radiators	thermostats, "Soft heating"
	Secondary heating system	open fire (5m^3 firewood/year)	heat pump (2,5kW), floor heating (1,5kW), open fire (2,5m^3firewood/year)			open stove in the basement	floor heating (8m^2)				
Hot water system	**Power**	3kW	integrated in the furnace		integrated in the furnace	3kW				3kW	3kW
	Boiler volume	200 liters	120 liters	200 liters	120 liters	300 liters	300 liters	300 liters	300 liters	200 liters	200 liters
Innovation	**Better insulation**	yes (5cm under windows and gables)	yes (attic)	yes (attic, 150mm)	yes (some of the walls 1964 - 73)		yes (attic)	yes (attic)	yes (attic)		yes (attic 340mm)

Bill Me This Way! – Customer Preferences Regarding Electricity Bills in Sweden

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Keywords

Electricity bill, feedback instrument, customer survey, energy behaviour, customer preferences, billing for actual use

Abstract

The liberalised electricity market in Sweden stresses the fact that the electricity companies must focus on customer satisfaction. Two major customer surveys concentrating on households' requirements concerning the electricity bill have been carried out in spring 2002. The interest in energy management lies within the fact that the electricity bill can be used as a feedback instrument to influence energy behaviour and the consumer's awareness of energy usage.

What kind of information do households really want on their bills? What do users think of the information they get on the bill today? How frequently do they want the bill to come? What information or which services should be included on the bill regarding content, design, medium and frequency? How important is it whether the bill is based on actual readings of electricity use and not just on preliminary estimates?

The experience of Swedish households indicates that the information included in the electricity bill is difficult to understand. Most customers feel that it is important that the bill is based on current readings of electricity usage. The electricity bills are not coming frequently enough to enable the households to relate their usage of electricity to habits and behaviour in everyday life. Historical information on the household's electricity usage could be added to the information in the bill to make such relations between electricity consumption and habits visible, although there are some limitations due to the format of the bills. The cost of the feedback is also an obstacle since neither the sender of the bill nor the receiver is willing to pay for the information.

Introduction

The power board customer plays a greater role now, since the de-regulation of the electricity market took place in 1996 in Sweden. The image of the energy consumer has changed from simply being seen as an anonymous load in the grid to being seen as a customer (Ketola & Matsson, 2001). The interest in knowing more about a specific customer has awakened. This interest stems not only from the current necessity to satisfy the customer needs, but information about the customers also helps the company to prioritise the customers who are most valuable to the company.

In relationship marketing, a relationship between the customer and the supplier exists. Although electricity is a service where the customers in general do not experience a high degree of engagement in the relation, this is said to exist when there is a contract between the customer and the supplier (Nyberg, 2002). Usually, there is not so much interaction and engagement in the relation between electricity suppliers and customers in general. The electricity bill is one of the few contact situations that occur, and the attitudes that the customers have to it is reflected on their evaluation of the service and the relationship.

In 1999, Wilhite, Høivik and Olsen reported that historical feedback on energy use led to energy savings and positive customer responses in an experiment in Stavanger. With historical feedback they mean data that shows how much energy the customer uses in every billing period of the current and previous years. Based on these results in Stavanger, the Norweigan Water and Power Authority (NVE) introduced new billing guidelines for all Norwegian utilities, effective in 1999. The guidelines require billing for actual use at a minimum of 4 times per year, and the incorporation of graphical historical feedback on the electricity bill (Wilhite et al, 1999).

The action taken in Norway also influenced the Swedish government to take interest in billing based on actual use. In 2002, the Swedish Energy Agency carried out an inquiry to see if a regulation of this type was desirable also in Sweden. The investigation has been widely debated by different actors in the Swedish electricity market, especially the grid companies who own the electricity meters. The association of the Swedish electricity utilities, Svensk Energi, commissioned a review of the Swedish Energy Agency report, where the calculations of costs to society were questioned. (A consultant company, SWECO Energuide made the review). The conclusions were that monthly readings of electricity meters are not profitable for customers using less than 8000 kWh per year. Instead of cogent legislation of monthly readings, they suggest that actual readings four times a year will enforce the electricity industry to gradually change to remote-controlled meters (SWECO, 2003-01-08).

Many operators in the Swedish electricity market have put a lot of money and effort into improving the electricity bill. In a press-release in October 2002 from Vattenfall– one of the leading energy producers and suppliers in Sweden and northern Europe – the company reveals that they, in a period of three years, are going to spend 600 million SEK (approx. 65 million EURO) on strategies to facilitate the situation for the electricity customers, e.g. easier meter readings, improved bills and new "electricity price products" (Vattenfall, 2002).

This article describes the results of two major customer surveys carried out during spring 2002, studying the households' preferences regarding electricity bills.

The attitude of Swedish households to the electricity bill

The first study (here called study 1) was commissioned by the Swedish Energy Agency (Energimyndigheten) in order to investigate the effect on energy behaviour and consumer attitudes towards billing for the actual use of energy. The study used a comparative research design with customer groups from three different electricity utilities (Smedjebacken Energi, Skånska Energi and Lunds Energi), where one of the utilities (Smedjebacken Energi) had been using billing based on current readings of electricity for some years. A questionnaire was handed out by mail to a random sample of customers of the three different electricity utilities (1000 households in each group). The frequency of respondents was approximately 35 % in all groups (Pyrko, Sernhed and Matsson, 2002). In this article the three groups are used as a base for descriptive statistics. Generalizations cannot be made for the whole Swedish population, only for the three different populations.

It was interesting to note that at the same time another study (here called study 2) was carried out by TEMO – a Swedish consultant company that deals with customer and opinion research (TEMO AB, 2002). Svensk Energi ordered this study. The method used here was telephone interviews based on a standardized questionnaire and the target group was "the ones responsible for the electricity bill". According to TEMO the findings represent the general public in Sweden from the age of 16.

In spite of the fact that those two surveys were carried out with different methodology, it was valuable to compare answers between the two studies because nine out of the sixteen questions asked in study 2 were exactly the same as in study 1.

Comprehension of the bill

In both studies, the majority of the respondents found the electricity bill difficult to understand. In study 1: 57 % of all cases found the bill hard or very hard to understand, and when comparing the three different customer areas, the one with the billing system based on actual readings (Smedjebacken Energi) showed a significantly higher understanding of the electricity bill than the other groups - 51 % thought the bill was hard to understand compared to 59 % (Skånska Energi), respectively 62 % (Lunds Energi). This could imply that the bills based on actual readings are easier to understand, although this result also could be due to other reasons, for example the fact that the design of the bills differed in the three different areas. In study 2, 52 % answered that the electricity bill was hard to understand.

The households find the information on the bill difficult because they experience expressions or concepts as beeing too complicated. They also feel that there is too much or too detailed information and sometimes the information is not specified clearly enough. These results correspond rather well in the two studies.

Another confusion for the customers is the fact that different parts of the bill are sometimes divided into different periods of time. Since the liberalisation of the electricity market, there have been two bills for electricity – one from the grid operator and one from the electricity supplier. When these actors coincide – although as different legal persons - the regulation permits a joint bill (which can be seen as a market advantage). The joint bill might be the reason why different periods of debit items occur on the same bill. This, however, weakens the customer relations and should be solved if the company is focusing on consumer satisfaction.

Billing system

Most of the electricity utilities in Sweden today use an invoice-system where people are billed several times a year for a theoretical fraction of their yearly electricity usage. The discrepancy between actual and estimated paid energy, is evened out on a final bill. In study 2, more than 9 out of 10 respondents stated that they have this type of billing system. When asked what billing system they would like to have, 69 % report that they would prefer billing on actual use, 22 % say they would prefer the pre-estimated invoice system and 8 % say that it doesn't matter to them what system they have. For the 8 out of 10 that prefer the pre-estimated invoice system, the reason is that they are satisfied with the way they are billed today.

In study 1 the results were similar, though there was one more option to choose from in the question put to them, namely pre-estimated invoice systems with a flat payment: 66 % preferred billing on actual use, 22% flat payment and 12 % wanted the pre-estimated invoice system. Those having the billing system of actual energy use were by far the most content with their billing system, but even those with a flat payment were quite satisfied with their billing system. This can be explained by the large part of households in electrically heated detached and semidetached houses represented in the population of study 1, and they have big fluctuations in their electricity costs since heating is season-dependent.

According to study 2, most of the customers who wanted to be billed for their actual energy use, were prepared to pay a small extra fee for each bill if based on actual readings. 63% agreed to pay 10 SEK (about 1,1 Euro) extra for each bill, 28 % agreed if they had to pay 20 SEK and only 6 % if the fee was 50 SEK extra.

The electricity bill as a feedback instrument

The electricity bill as a feedback instrument is a form of indirect feedback. The energy saving potential for indirect feedback is not as big as for direct feedback, which is always available when needed (Darby, 2000). However, there have been examples of significant energy savings due to feedback information on electricity bills (see for example Wilhite and Ling, 1995).

Feedback can be defined as the control of a system or a process. It is the information of the result of the system or the process. It is also a necessary part of learning, and here, a satisfactory frequency of the feedback is important to enable some understanding of cause and effect.

On the electricity bill the households get information on their latest consumption of electricity and the cost of that. This feedback could alert the costumers to focus more on their energy use (in order to save costs). A billing system based on actual readings clearly provides more reliable basic data for feedback, because it better reflects the household's actual energy use than the bills based on preliminary estimations. Nevertheless, the bills do not come that often (4-12 times a year) and therefore this feedback is not frequent enough to enhance the household's understanding of how specific behaviours or everyday routines influence the consumption of electricity.

Symbolic meanings of the electricity bill

The electricity bill has several different symbolic meanings and areas of usage. In table 1, different areas of usage are listed and organized in a company-customer perspective.

Table 1: Different areas of use of the electricity bills in a company-customer perspective.

Symbolic meaning and areas of use	Electricity utility	Customer
Invoice	To get payment for executed services.	To get information of costs and instructions of payment
Market document	An opportunity to present the company and to reinforce the company profile.	
Control tool		To be able to control if the cost of electricity is reasonable and if the reported use of energy corresponds with the electricity meter.
Feedback instrument	An opportunity to offer the service of feedback information to the customer	If interested, the customers can get valuable information on their energy use.

Statistical information on energy usage

Households were asked if they would like to get more specific information about their energy consumption on the electricity bill or via the Internet (study 1). The answers from the three different customer areas are here merged into one group, although the answers were very much the same in all groups for all questions about specific feedback information. The answers are compiled in figure 1:

- **Warning:** Nearly 90 % of the households wanted to be alerted if the energy consumption suddenly increases.
- **Graph:** Around 75 % wanted a graphic presentation of the actual consumption compared with the consumption the same month the previous year.
- **Tips:** About 65 % wanted energy conservation tips incorporated into the bill.
- **Norm:** Just about 50 % wanted comparative statistical information from a comparable household.
- **Internet:** The least popular kind of information was statistical information via the Internet - 33 % were positive and 50 % negative. This should be put in relation to the fact that about 75 % of the households have stated that they have access to the Internet at home or at work (64 % have access at home). So the accessibility is not solely the reason that the interest here is lower.

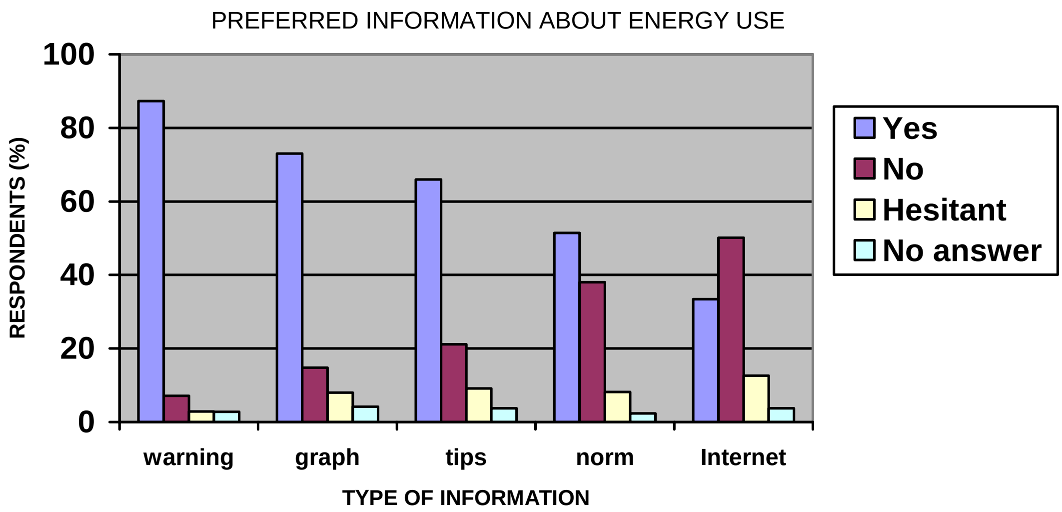

Figure 1: Consumer preferences regarding different types of information on energy use (study 1).

The households were also asked if they would be interested in these services if they had to pay for them. Only 24 % were interested if there was a cost attached to the services. 16 % stated that they were only interested if the cost was very small.

Frequency

Both study 1 and study 2 show that most people tend to be satisfied with the frequency they get the bills today (each month, every other month or quarterly). This might imply that this question is of no great importance to the customers. People who live in detached or semidetached houses want the bill to come more frequently than those living in flats (study 2) and usually these households already get the bill more frequently than customers in flats today. This can be explained by the need to split the cost into shorter periods.

Different ways of reading the bill

Different ways of reading the bill can reflect the different needs of the customer. In study 1, the households with high electricity costs in relation to the total household budget tend to read the electricity bill more carefully (Table 2).

Table 2: Cross table over the proportion of the electricity cost in a household in relation to total household budget compared with how carefully the electricity bill is read.

The cost of electricity in relation to household budget	Percentage of households that read the electricity bill carefully	
	Yes	No
Very large part	65	34
Large part	63	37
Moderate	53	47
Small part	45	54
Very small part	41	59
Don't know	41	58
Totally	53	46

Results showing that the feedback is more efficient when the energy cost stands for a larger part of the household budget has also been found in earlier research, see for example Constanzo et al. (1986).

The experiences from Svensk Energi are that there are different types of readers of the bill: those who just skim through the information on the bill, those who read the information to see if it is reasonable and those who check the reported meter readings against the electricity meter. Then, there are "inspectors" who control all the received information. Because "the inspectors" are the group who most often contact the energy companies, the electricity bills have more or less been designed after their wishes (Svensk Energi, 2002).

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II

Pay for Load Demand
Electricity Pricing with Load Demand Component

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load demand, electricity pricing, tariff, residential customers, energy behaviour

Abstract

This publication is part of a project called Direct and Indirect Load Control in Buildings performed at the Division of Energy Economics and Planning, Department of Heat and Power Engineering, Lund University, Sweden.

Peak load problems have attracted considerable attention in Sweden during last three winters, caused by a significant decrease in available reserve power, which is a consequence of political decisions and liberalisation of the electricity market. A possible way to lower peak loads, avoiding electricity shortages and reducing electricity costs both for users and utilities, is to make customers experience the price difference during peak load periods and, in this way, become more aware of load demand.

As of January 1st 2001, one of the Swedish energy utilities - Sollentuna Energi - operating in the Stockholm area, introduced a new electricity tariff with differentiated grid fees based on a mean value of the peak load every month. This tariff was introduced for all residential customers in the service area.

The objective of this study is to investigate the extent to which a Load Demand Component, included in electricity pricing, can influence energy use and load demand in residential buildings. What are the benefits and disadvantages for customers and utilities ?

This paper investigates the impact of the new tariff on the utility and different types of typical residential customers, making comparisons with previous tariff.

Introduction

After the liberalisation of the Swedish electricity market in 1996, many things have changed in the marketplace. The liberalisation has kept the electricity prices at the same level as in 1996 and has made customers able to choose the electricity supplier that best fits. However, not all consequences of the de-regulation have been positive, some problems have appeared too. Due to predominantly economic and political reasons, the load reserves have dwindled while the load demand keeps increasing 2 % every year. In Sweden, the problem of load capacity is getting more serious as is the necessity for solutions. The prices began to rise again in 2001 and this trend continued during 2002.

In order to achieve lower load demand and avoid load peaks, one Swedish electricity utility, Sollentuna Energi, introduced a new component into the electricity tariff, with different charges depending on the average value of three load peaks obtained every month.

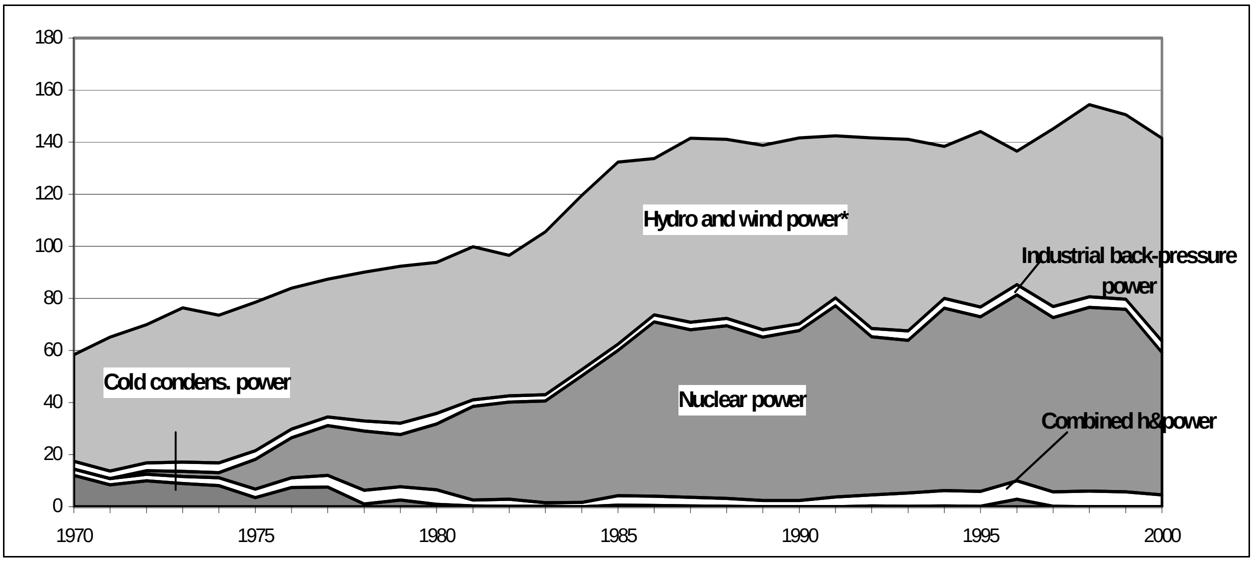
The objective of this study is to investigate how tariffs can change the habits of electricity consumption in different groups of residential customers. The goal is to lower load demand and avoid load peaks. This way, the risk of electricity shortages will decrease. This report studies also the influence that this new load component is likely to have, not only on the use of electricity and the load demand, but also on the cost of electricity for the customer.

Electricity market in Sweden

Electricity supply

At the beginning of the 1970s, electricity was generated in Sweden by means of thermal power plants and hydropower. Due to the oil crisis and environmental laws, the construction of nuclear power plants commenced. Since 1975, more electricity is produced by nuclear power plants than by conventional power plants (STEM, 2001b).

Nowadays, electricity is produced in Sweden mostly by means of hydropower and nuclear power. Conventional power plants are used as well, but today they represent no more than 6% of the total electricity production, being used as a reserve capacity. Nevertheless, many of them are being closed due to the reformation of the electricity market - for economic reasons. The wind power contribution is increasing but still constitutes a very small part, amounting to 0.3% in 2000 (see Figure 1). In Sweden, the total installed capacity of power plants is over 30,000 MW. However, this load capacity cannot be continuously available at a 100% level. During some critical periods electricity balance depends strongly on import possibilities. Furthermore, there can arise some problems with the transmission of energy between the north and south of Sweden (STEM, 2001b).



*Wind power since 1997

Figure 1. Electricity generation in Sweden - TWh/a (STEM, 2001b).

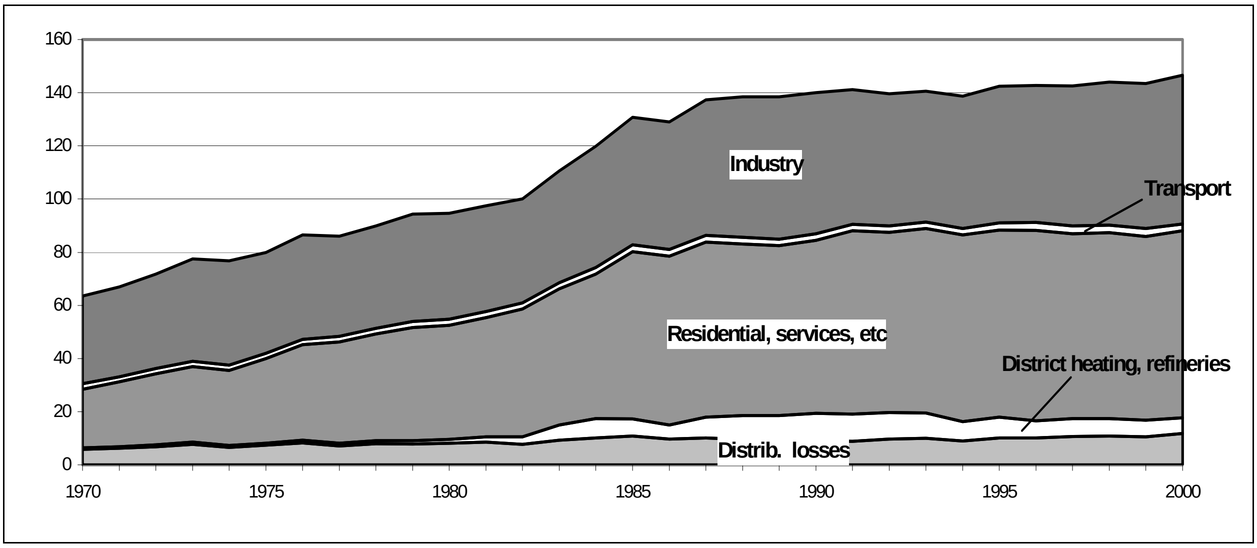


Figure 2. Electricity use in Sweden by sectors - TWh/a (STEM, 2001b).

Electricity use

Over the past thirty years, electricity consumption in Sweden has constantly been increasing at a rate of about 1-2% per year and nowadays the demand is close to 150 TWh/a (see Figure 2).

This equals approximately 16.52 MWh/a per capita, which is one of the highest electricity consumption levels per capita in the world (Pyrko, 2001).

The most important increase is to be found in the residential sector, due to the change from oil to electricity for heating. This is why there is a strong relationship between ambient temperature and electricity consumption (STEM, 2001b).

Electricity use in the Swedish industry has increased too. In this case, consumption is linked to the evolution of a small number of important industries such as pulp and paper, which consume about 40% of the total electricity used in the industry (North, 2001).

The industry and the residential sectors are the two major sectors in terms of electricity demand. However, there are others, like the transport sector and district heating plants. The total electricity demand also takes into consideration losses associated with the transmission of electricity (STEM, 2001b).

Table 2.1 below shows more detailed facts about electricity generated and consumed in Sweden with forecasts for year 2010.

Table 1. Electricity generated and consumed in Sweden in 1990, 1995-2001 and forecasts for 2010, TWh/a (STEM, 2001a).

	1990	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2010**
Generation	142.2	143.9	136.0	145.2	154.6	150.9	140.1	157.8	149.4
Hydro power	71.5	67.0	51.0	68.2	73.8	70.7	76.4	78.5	67.0
Wind power	0	0.1	0.1	0.2	0.3	0.4	0.4	0.5	2.0
Nuclear power	65.3	67.0	71.4	66.9	70.5	70.2	54.7	69.2	68.3
Other thermal power	5.6	-	13.5	9.9	9.9	9.6	8.6	9.7	12.1
CHP in industry	3.1	3.8	4.5	4.2	4.0	4.5	4.2	4.4	4.9
CHP in district heating	2.1	5.5	5.4	5.3	5.7	4.9	4.2	5.2	7.0
Condensing power	0.3	0.4	3.6	0.4	0.2	0.2	0.2	0.1	0.2
Gas turbines	0.1	0.1	0	0	0	0	0	0	0
Consumption	139.7	142.2	142.2	142,5	143.9	143.4	144.8	150.5	154.6
Network losses	10.7	8.3	9.4	11.6	12.7	11.4	10.7	12.1	11.3
Imports-exports	-2.5	-1.7	6.1	-2.7	-10.7	-7.5	4.7	-7.3	5.2

Electricity price and taxes

In the actual Swedish electricity market, post de-regulation, customers can choose the company they wish to buy electricity from. Once the customers are connected to the network, they are free to look for the supplier who is best suited. The liberalisation of the electricity market is not yet complete as the network supply is still a monopoly.

Electricity charges vary between different customer groups. This is due to the structure of the electricity market, differences in taxation, and varying distribution costs. The final price is determined by the equilibrium between supply and demand.

Post liberalisation, electricity prices were dropping until the end of 2000 when energy production was reduced with the objective of increasing prices again. Since the beginning of 2001, the cost of electricity has been increasing, and this trend seems to be stable (Pyrko, 2001).

Trade takes place through the electricity exchange, which is regulated by the Nordic Power Exchange, called “Nord Pool”. This organisation was the first electricity marketplace in the world and has been operating since 1993. The benefit of trading through Nord Pool is that transactional costs are lower than those for bilateral agreements. In fact, it is typically cheaper to import peak load electricity than to generate it domestically.

The end-user's bills

Typical end-users receive two bills, one from their electricity supplier and a second one from their electricity network owner (some utilities have nowadays only one compiled bill). The total electricity charge consists of: the price of electrical energy, a network fee and taxes.

As is shown in Figure 3, within each of these two bills (network fee and electricity fee) charges are divided into two parts. The first part is a variable fee, dependent on the amount of electricity (kWh) used. The second part is fixed, independent from the consumption. The fixed part of the network fee is based on the value of the main fuse used in the household, and the variable part is the charge for transmission and service of the network. The fixed part of the electricity fee is due to a subscription fee, which is charged by the electricity supplier.

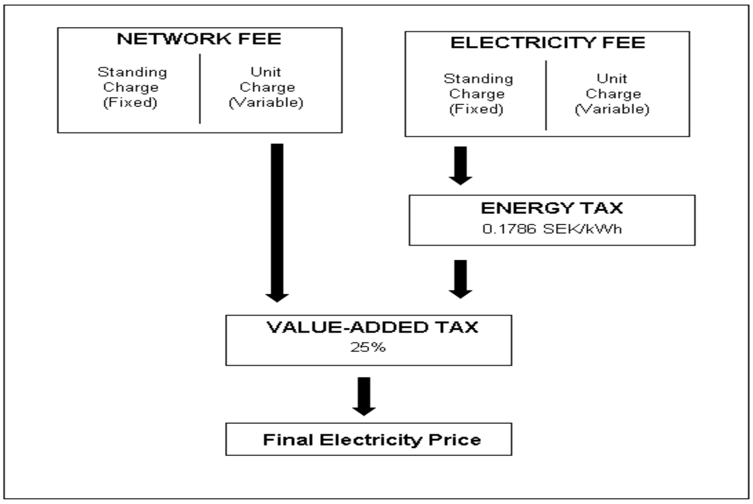


Figure 3. Composition of the total electricity price for domestic customers in 2001 (North, 2001).

The price of actual electricity purchased by a customer is about 25% of the total electricity price to Swedish domestic customers. The network tariff accounts for 35%, and taxes represent about 40%. As can be seen, taxation is the most expensive part of the bill. This is the main reason why the total price which end-users have to pay, has not changed significantly since 1996 and will rise all the time according to political decisions (STEM, 2001b).

The price of electricity to the customer

Due to increased competition, electricity trading companies have been forced to adjust their prices. This happened until the beginning of 2001 when prices started to rise again. The price of electricity for customers living in single-family houses without electric heating increased by 3.4% and for customers with electric heating, by an average of 3.2% (STEM, 2001b). Electricity prices continued rising during 2002.

The rise in price was the most important reason why, in February 2001, about 15% of Swedish households had changed their electricity suppliers. This represented a big difference from February 2000 when only 7% of the households had changed their suppliers.

The change of supplier was easier to carry out because of the regulation introduced in November 1999, which allowed customers to choose their electricity suppliers for free, on the first day of any month.

The network tariff

The network tariff represents the charge for the transport of the electricity and for making the connection to a power line or to a power line network. Customers cannot choose their network, so network tariffs must be reasonable and non-discriminatory. In order to reach this objective, network tariffs have to be published and supervised by the National Energy Administration.

Customers are classified into groups according to their main characteristics - depending on whether they have electric heating or not, and whether they have a time tariff or not. Furthermore, customers in the same group have to be charged from the same network tariff and the tariff must not be different depending on the area in which a customer lives. Since 1996, the network tariff has increased by on average 3%.

Viewed overall, the network tariff has increased for customers whose electricity consumption is low. For customers with high electricity demand, the network tariff has dropped.

The taxation system

In Sweden, the consumption of electricity is taxed. The end-customer has to pay two different taxes, the energy tax and the VAT (Value Added Tax) that is applied to the total price of electricity, including the energy tax. Nevertheless, the increase of the carbon dioxide tax makes electricity cheaper in relation to other energy sources.

The energy tax value for households is not the same in all of Sweden, varying (2001) between 0.148 SEK/kWh in northern Sweden (1 SEK = aprox. 0.11 EURO) and 0.181 SEK/kWh in the rest of the country (STEM, 2001b).

Electrical energy is taxed at the generation level too. All fuels used for the generation of electricity are exempt from energy taxes. However, a part of this fuel is considered as in-house used and is therefore taxed. This is why every fuel used for electricity generation is subject to environmental taxes, such as Nitrogen tax and Sulphur tax.

Load problems in Sweden - general overview

In order to see how electricity consumption varies, it is appropriate to talk about load demand, expressed in kW or MW. The Swedish network is dimensioned on total energy need, which is not useful if load demand cannot be delivered on a momentary level. This is the most important reason for system blackouts.

A further consequence of the liberalisation of the energy market is that many energy generation plants have been decommissioned or preserved for economic reasons. As a consequence, the amount of reserve capacity plants has dropped, resulting in the margin between maximum load capacity and maximum load demand decreasing, as shown in Figure 4 (North, 2001).

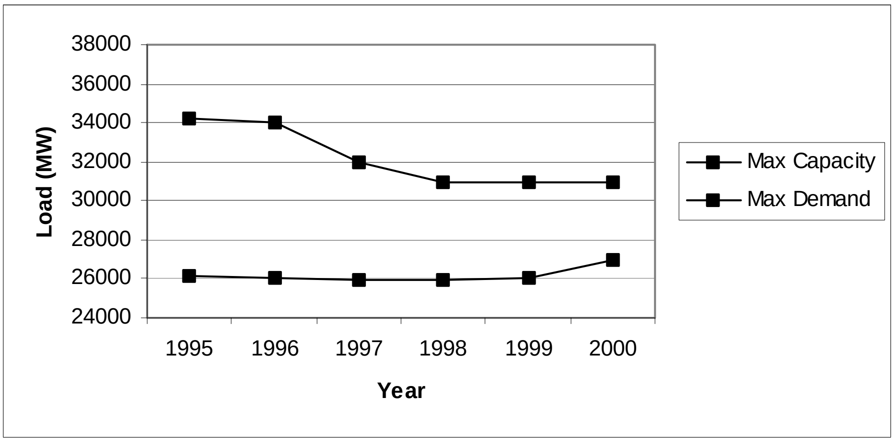


Figure 4. Sweden's installed load capacity and load demand 1995-2000 (North, 2001).

The margin between load capacity and load demand has dropped from 23.0% in 1996 to 12.6% in 2001. If this trend continues the Swedish network will not be able to supply the load demand and Sweden may experience serious power shortages.

This problem seems to be more impending if we study the main areas of production and consumption of electricity in Sweden. The highest demand is located in southern Sweden, where the majority of Sweden's population resides. However, the most important areas for energy generation are located in the north of Sweden. This means that it is necessary to transfer electricity from the north to the south and even to buy electricity from other countries. As is shown in Table 2, the south of Sweden is highly dependent on load imports.

Table 2. Regional balance in Sweden for winter 2000/2001 (North, 2001).

	Southern Sweden	Northern Sweden
Total Available Load Capacity	16238 MW	12502 MW
Expected Load Demand	23220 MW	4880 MW
Regional Load Balance	-8182 MW	7018 MW
Load Transfers		
From within Sweden	6500 MW	-6500 MW
From the rest of Scandinavia	1550 MW	0 MW
Other Transfers	570 MW	0 MW
Load transfer Balance	8620 MW	-6500 MW
Final Load Balance	438 MW	518 MW

This problem is even more serious since the shutdown of one of the nuclear power reactors, Barsebäck 1, which involved the loss of 600 MW in southern Sweden.

The solutions to this problem cannot easily be found. Firstly, the reserves of load generation are dropping for political reasons (the decommissioning of nuclear power plants) and for economic reasons (the decommissioning of conventional power plants). On the other hand the load demand is increasing due to the use of electric heating, especially on the coldest days of winter. It is known that the inverse relationship between load demand and temperature in Sweden is approximately 350MW/°C in total.

The conclusion to this section is that if Sweden does not increase its load capacity or compensate for the low production with "negawatts", it is obvious that Sweden will not be able to meet the load demand. This would increase the dependency on neighbouring countries, increasing the price of electricity and the possibility of power shortages.

Different solutions to the load problem

Obviously, there are two ways to solve the problem of load capacity. One is on the supplier side, and the other one is on the demand side. On the supply side the most popular solution so far has been to produce more electricity, building more power plants and increasing the electricity generation. Since the re-regulation, this solution is not economically viable. This is because the electricity market is more competitive and as such, production has to be dropped as much as possible as the fixed cost of electricity production is too high. This is the reason why many power plants have been decommissioned. The supply-side nowadays includes energy storage technologies, such as pumped hydro, or waste-to-energy generation, co-generation and reduction of energy transmission losses.

On the demand-side, the goal is to level out the consumption of electricity, in order to reduce the peak load demand and to keep the margin of load capacity big enough to ensure supply of electricity at all times.

There are several ways to reach this objective (Abaravicius, 2002; Association of Energy Services, 2001), such as:

- Direct Load Control (DLC): This type of control programs activities that can interrupt the electricity supply to a customer’s individual appliances or equipment. DLC can be used on equipment that can be switched off with short notice. DLC usually involves residential customers.
- Time-Of-Use Tariff (TOU): This strategy of management uses different types of tariffs to encourage customers to eliminate consumption during peak periods. TOU is designed to reflect the utility cost structure where rates are higher during peak periods and lower during off-peak periods. TOU tariffs based on peak load pricing have been introduced in recent years, having proved to be one of the most efficient strategies in load management. Both the supplier and the end-user benefits from successfully designed TOU rates.
- Interruptible Load Tariffs: This type of tariff consists of incentives, which are given to customers for interrupting or reducing the power consumption during peak periods or in emergency conditions. When customers sign an interruptible load contract they have to reduce their electricity consumption as and when requested by the utility.

Case - Sollentuna Energi

In this part of the paper, one practical case will be analysed. The aim of this part will be to highlight the influence of the changes in electricity tariffs on electricity consumption, through differences in data from 2000 and 2001. This is the most important part for the electrical utility. Furthermore, since the electricity price is the most important factor in the change of the tariff on the customer side, an economic study will be included.

Sollentuna Energi is a Swedish energy utility which operates in the Stockholm area, supplying electricity to about 24,000 customers: 12,000 flats, 8,000 villas and 4,000 terraced houses. Sollentuna Energi is also one of the Swedish energy utilities, which have recently installed remote metering/billing systems based on 1-hour measurements, stored in databases. The system is fully implemented and is used for both data collection and billing.

The utility’s maximum contracted load capacity is 106 MW. The contracted load level was exceeded on February 5th 2001, between 8:00 and 9:00 am, by a maximum peak load with a value of 112 MW. This peak of consumption took place during a particularly cold period in Sweden. It is obvious that load demand is influenced by the climate; in fact about 40% of the total demand in this region is climate dependent. As the previous example shows, Sollentuna Energi has a problem of load capacity that becomes even more serious during cold periods (Sollentuna, 2002).

Since January 1st 2001, Sollentuna Energi is the first energy utility in Sweden to have incorporated a load component into its grid tariff. This load charge depends on an average load value of three hourly load peaks during one month.

The difference between the previous ordinary tariff (2000) and the new load tariff (2001) is explained below:

Ordinary Tariff: Cost (SEK) = [(Energy * 0.08 + 127) + Energy * 0.555] * 1.25.

This expression has two different parts, **the grid fee** "(Energy * 0.08 + 127) * 1.25" and **the energy fee** "Energy * 0.555 *1.25". Taxes are included in both expressions. Where:

- *Energy* is the electricity consumption during one month.
- 0,08 (SEK/kWh) is the Unit Charge of the network fee.
- 127 (SEK/a) is the Standing Charge of the grid fee. It is also called fuse level fee.
- The two previous values are multiplied by 1.25 because of the 25 % Value-Added Tax (see Figure 3).
- 0,555 is the electricity fee, including taxes.

Load Tariff: Cost (SEK) = [(P_{av} * C + 55) + Energy *K] * 1.25

This tariff also has two different parts, which are separated as in the ordinary tariff, **the grid fee** "(P_{av} * C + 55) * 1.25" and **the energy fee** "Energy *K * 1.25". Where:

- P_{av} is the average of the three highest peaks of load consumption every month on different days.
- C is a constant and takes the value of 21 from April to October and 42 from November to March.
- P_{av} * C is the Unit Charge of the network fee.
- 55 is the Standing Charge or fuse level fee of the network tariff.
- The two previous values are multiplied by 1.25, because of the Value-Added Tax.
- Finally, K is the energy fee and takes the following values: 0.499 from January to April, and 0.555 from May to December. Taxes are included.

1 SEK = aprox. 0.11 EURO (2002)

The main objective of the load component in tariffs was to make the end-users more conscious of load capacity problems. The long-term aim is to reduce the load demand in the whole service area in order to decrease the level and the price of load contracted from the electricity supplier and secondly, to avoid expensive investments necessary to strengthen the grid.

First of all, it is necessary to be conscious of the fact that the climatic conditions were different in 2000 and 2001 and as such so was the total energy consumption. The analysis has to be carried out from a general point of view because there are many other influencing factors that will not be considered in this study.

Maximum and minimum 1-hour total load demand for every month during 2000 and 2001

The diagram (Figure 5) shows the extreme load demand values in 2000 and 2001 expressed in kWh/h.

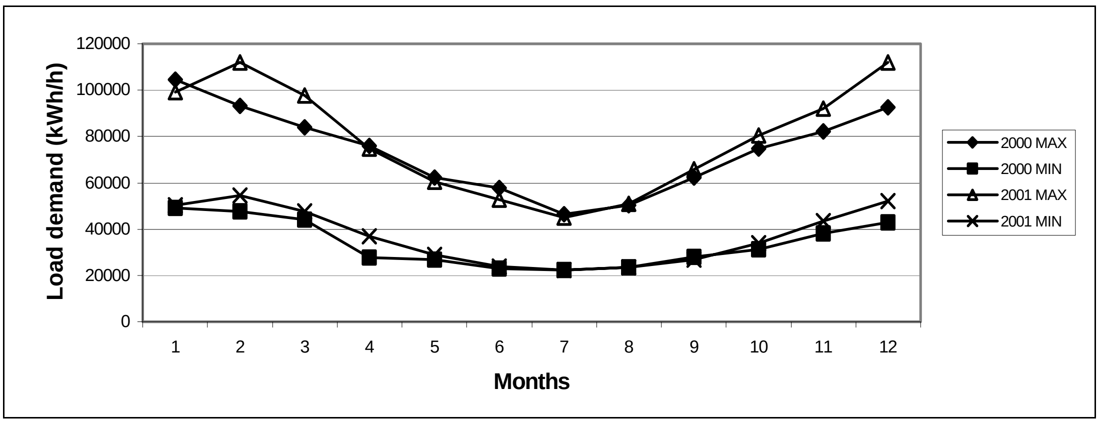


Figure 5. Maximum and minimum 1-hour total load during 2000 and 2001.

Despite the values being quite similar in 2000 and 2001 there are differences and some interesting aspects to emphasise. Firstly, in February, March and December, the maximum values of load demand were significantly higher in 2001 than in 2000. Secondly, during the warmest period of the year, between April and September, the maximum values of load demand were very close for both years. During the winter period from November to March, every month apart from January were colder. These facts highlight the relationship between climatic conditions and electricity consumption in Sweden, specially for electric heated dwellings.

It is also interesting to look at the margin of load capacity for every month. This factor is expressed as a percentage of $P_{h, max}$ (the maximum 1-hour load demand value for each month), and 106 MW, which is the utility's maximum contracted load capacity. These values are shown in Figure 6. This figure shows Sollentuna Energi's problem with load capacity, which was particularly serious during very cold periods like January 2000, February 2001 and

December 2001. In fact, when the Degree Day value for this area is higher than a certain value (approximately 560), the margin of load capacity is not large enough to secure the supply of electricity.

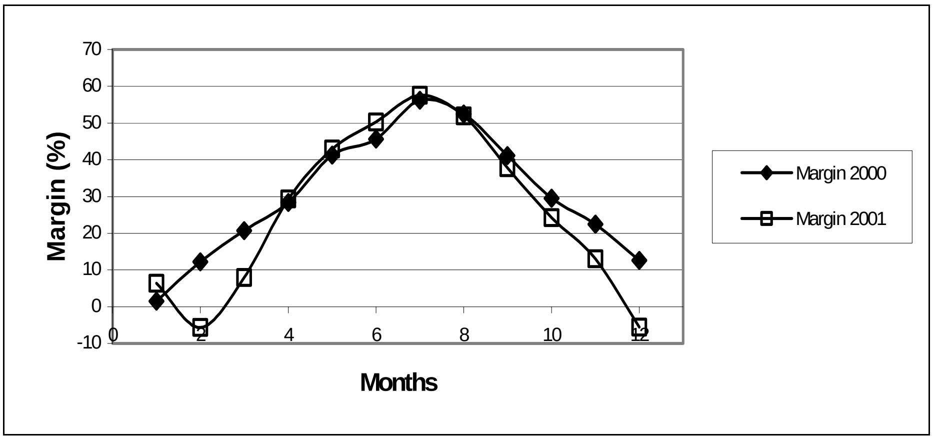


Figure 6. Margin of load capacity of Sollentuna Energi in 2000 and 2001.

Duration curve from a 1-hour load demand for the years 2000 and 2001

Figure 7 shows the values of 1-hour load demand during 2001 placed in decreasing order so that it is possible to establish the number of hours when the consumption has been higher than a certain value. The highest values represent the peaks of load demand during the studied year. The lowest values represent the base load of the utility. The total energy consumption during a year is also shown; it is the area below the curve. A greater amount of important information is available from these curves than from the 1-hour average load demand in a year, from the total energy consumption and the number of hours of the year. Also, the shape of these curves is interesting because it reflects the values of load demand which are more common as well as those that are not frequent. The flatter the slope of the curve, the more frequently the load demand value occurs.

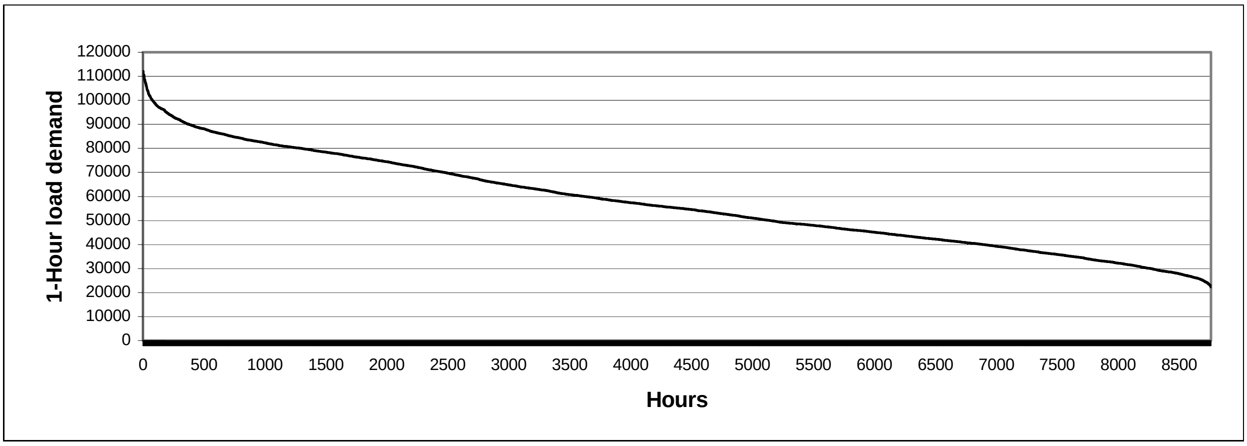


Figure 7. Duration curve from 1-hour total load curve for 2001.

From the source data of these curves the following information is available:

Table 3. Number of hours with high consumption, total electricity consumption and average of load demand 2000 and 2001.

Load demand higher than	2000	2001
>110 000 kW	0 h	8 h
>100 000 kW	8 h	78 h
>90 000 kW	90 h	378 h
Total energy use (GWh/a)	468.3	500.7
Average load demand (MW)	53.309	57.164

As is shown in Table 3, the consumption in 2001 was higher than in 2000. On the other hand, the shapes of the duration curves are similar, with approximately 400 hours per year when the consumption is much higher than the values expected, considering the trend of the curve.

Monthly Load Factor (LF_m) for each month during 2000 and 2001

This factor is calculated as $LF_m = P_{h, av} / P_{h, max}$ and expresses the relative value of the highest peak load in relation to the average load consumption during one month. Values close to 1 indicate that the load curve is smooth, which is the desired objective. The values of LF_m in 2000 and 2001 are shown in Figure 8.

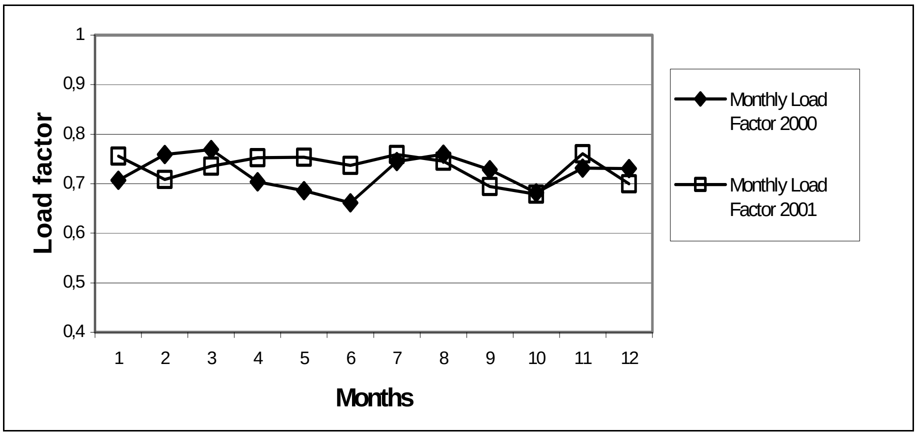


Figure 8. Monthly load factor for each month during 2000 and 2001.

The average of this factor was 0.72 in 2000 and 0.73 in 2001. In addition, the values of LF_m were more uniform in 2001. Notwithstanding this, the differences are not as large as expected. The most considerable improvement occurs during January, April, May and June.

Monthly Average Load Deviation for each month during 2000 and 2001

This factor is calculated as $ALD_m = \Sigma(P_{d, max} - P_{d, min})/n$. High values indicate that the consumption has been very irregular during a particular month, with big differences between maximum and minimum values of daily load demand. This factor took the following values during 2000 and 2001:

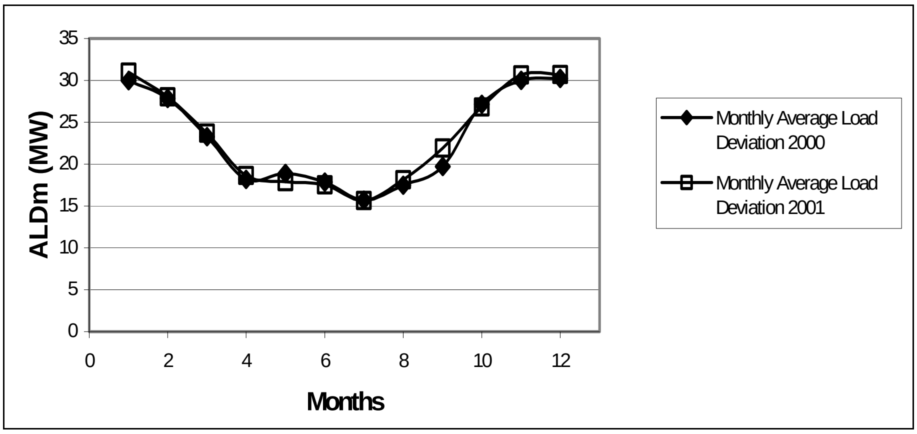


Figure 9. Monthly average load deviation for each month during 2000 and 2001.

As is shown in Figure 9, this factor takes higher values during the coldest months of the year. Notwithstanding this, there are no significant changes from 2000 to 2001. The trend is virtually the same for both years, and as such no relevant information or conclusion could be extracted from the study of this factor.

CUSTOMER ANALYSIS

In the following section, fifteen of Sollentuna Energi's customers will be analysed. These customers are grouped into three different categories: flats, villas and semi-detached houses. The analysis will focus on two different approaches. Firstly, an economic study will be conducted, in order to establish the changes in electrical expenses for customers due to the new tariff. Secondly, changes in consumption patterns will be discussed. This part of the analysis will be made from the utility point of view, in order to establish whether the objectives have been reached.

FLATS (with district heating)

Five customers in flats will be analysed. They are all district heating users, so the values of electrical consumption are not climate dependent. Furthermore, their fuse level is 16A, which is the lowest fuse level of all the customers studied. There were some problems with the meters for two of the customers, Flat D and Flat E, so some data is unavailable.

In the economic study of the cost of electricity for each customer, a comparison between the ordinary tariff and the new load tariff has been made (Pérez Mies, 2002).

This study has considered the electricity consumption in 2001, comparing the real cost of the new load tariff with the cost of electricity that the customer would have paid with the old tariff, called "ordinary tariff".

Changes in consumption patterns have also been studied using two indicators: the Monthly Load Factor and the 10 highest values of load demand in each month, during 2000 and 2001.

These factors will show whether the main objective of the new tariff - making the highest peaks lower - has been achieved. Despite the use of district heating, an overview of climatic conditions is interesting, because electrical consumption does not depend on the weather but is related to the season.

MOST RELEVANT DATA AND GENERAL OVERVIEW FOR FLATS

The most relevant information from the flat customers is shown in Table 4 summarised in main points as follows:

- Money saved. The amount of money saved.
- Saving (%). Amount of money saved expressed in percent.
- Highest peak. Highest value of load demand during one year.
- Monthly Load Factor (average). Average of this factor during one year.
- Also expressed is the relative load factor change (%), which is calculated as: $(LF_{m2001}-LF_{m2000})/ LF_{m2000}*100$.

Table 4. Summary of the most important data from flats.

	Money saved (SEK)	Saving (%)	Highest peak (kW)		Monthly Load Factor (average)		Load Factor Change
			2000	2001	2000	2001	%
Flat A	555	18,0	2,3	3,2	0,108	0,114	5,1
Flat B	515	11,0	4,0	3,0	0,201	0,195	-3,0
Flat C	335	10,5	4,0	4,0	0,083	0,091	9,7
Flat D	577	20,5	2,6	3,1	0,166	0,147	-11,0
Flat E	403	11,5	3,0	3,0	0,181	0,172	-5,1

It is of interest to emphasise that the meters of customers B, C and D work with integer values only, and as such the results are not as exact as preferred. Despite the fact that the final result does not change that much, the margin of error becomes bigger when the consumption is low – as in this case for flats.

ECONOMIC STUDY

As shown in Table 4, the new tariff is very profitable for customers in flats. All of them are now paying less than they did with the ordinary tariff.

The amount of money saved is not really significant, (savings vary from 335 to 577 SEK per customer per year), however this amount is very important considering the price of electricity for these customers. In fact, their expenses are now between 10 and 20 percent lower.

During the summer period the cost of electricity is considerably lower, sometimes up to 30 percent. This enables customers to consume electricity as they wish during the winter period and still save money considering the whole year.

STUDY OF ELECTRICITY CONSUMPTION PATTERNS

For the utility, the profit is not as obvious as for the customers. In fact, the Monthly Load Factor is lower for three out of five customers, and just one customer has reduced the highest load peak.

Some customers have reduced the number of hours with consumption higher than a certain value, but this finding is not obvious enough to conclude that the new tariff has improved the habits of electrical consumption for these specific customers.

ONE-FAMILY VILLAS (electric heating)

The next five customers are villas with electric heating. Their fuse level is 25 A, the highest of all the studied customers. As they use electric heating, a study of climatic conditions is obviously necessary. However, the economic study is made only with data from 2001, comparing real cost with the new tariff versus hypothetical cost with the old (ordinary) tariff, so the economic part of the study does not include climate dependency. The cost of electricity has been calculated as before for customers in flats; the only difference is the cost of the fuse level.

The meters of two of the customers work only with integer values. This reduces data precision but is not as important as in the case with the flats, because the overall electricity consumption of customers in villas is much higher, as and such the impact of integer values is lower.

MOST RELEVANT DATA AND GENERAL OVERVIEW FOR ONE-FAMILY VILLAS

The most important information from five one-family villas is summarised in Table 5.

ECONOMIC STUDY

As before, the new tariff is also very profitable for villa customers. The percent of money saved is lower than in the previous case, but the amount of money is much more significant. The price differences are more significant during the summer period; in fact the grid fee is cheaper for each customer from April to October.

Table 5. Summary of the most important data from villas.

	Money saved (SEK)	Saving (%)	Highest peak (kW)		Monthly Load Factor (average)		Load Factor Change
			2000	2001	2000	2001	%
Villa A	3632	10,0	14,9	14,6	0,508	0,510	0,54
Villa B	1857	10,5	8,7	9,6	0,279	0,305	9,33
Villa C	855	3,0	17,0	17,0	0,259	0,294	13,40
Villa D	1555	7,0	13,0	15,0	0,286	0,313	9,33
Villa E	1649	8,2	13,2	13,1	0,271	0,337	24,50

These customers are the users of electric heating so their energy consumption is much higher during the winter period. This has to be considered, as the energy fee was lower during the first four months of the year. With the actual energy price (valid since May the 1^{st}) the cost of electricity with the new tariff will be higher for weather dependent customers during the period January to March. These customers are Villas C, D and E. In fact, all of them are paying more with the new tariff during the two last months of the year, except Villa E in November.

STUDY OF ELECTRICITY CONSUMPTION PATTERNS

All customers have improved their Monthly Load Factor, which is beneficial for the electrical utility. Despite this, the highest peak is lower for just two customers out of five.

Moreover, it is interesting that the customer who saved the greatest amount of money (Villa A) has the lowest improvement in the Monthly Load Factor. On the other hand, this customer is one of those who have reduced the highest peak of consumption, which means that the benefit, in terms of money saved, to the customer is more dependent on the highest value of load demand than on the LF_m.

Although 2001 was much colder than 2000, the top values of load demand are not higher. The number of hours that the load demands of Villas A and C were higher than a certain value, are significantly lower in 2001 than in 2000.

The conclusion from the analysis of these customers is that there has been a slight improvement in their consumption habits. However, from the utility point of view, this improvement does not seem to be sufficient to compensate for revenue losses.

SEMI-DETACHED HOUSES

The last five customers live in semi-detached houses. The power consumption among them should differ, since three of them use electric heating (with a fuse level of 20 A) and two have district heating (with a fuse level of 16 A).

The study of these customers is very interesting because it enables the observation of the influence of climate conditions on power consumption. If we assume that the household electricity consumption is rather similar in all these houses, the differences should basically occur due to the electric heating, which is obviously extremely dependent on climate conditions.

The cost of electricity has been calculated using the same formulas as in the previous cases, changing the value of the fuse level charge.

MOST RELEVANT DATA AND GENERAL OVERVIEW FOR SEMI-DETACHED HOUSES

The most important information from the analysed customers is summarised in Table 6.

Table 6. Summary of the most important data from semi-detached houses.

	Money saved (SEK)	Saving (%)	Highest peak (kW)		Monthly Load Factor (average)		Load Factor Change
			2000	2001	2000	2001	%
Semi-detached A	1254	10,0	6,6	7,3	0,296	0,298	0,7
Semi-detached B	912	9,9	6,3	7,3	0,209	0,219	5,0
Semi-detached C	783	7,8	6,3	7,0	0,206	0,228	10,6
Semi-detached D	367	4,6	5,6	5,1	0,249	0,241	-3,0
Semi-detached E	349	3,7	5,5	6,0	0,236	0,262	11,1

ECONOMIC ANALYSIS

The economic analysis conclusions for this group of customers are broadly the same as for the previous customers. All of them are saving money, especially during the summer period. This saving (together with the fact that the energy price was lower during the first four months of the year) allows the customers to save money despite their load consumption during the winter period. With the load tariff, the expenses were higher for Semi-detached houses C, D and E during every month in the winter period from November to March, due to the grid fee. However the yearly cost of electricity was lower for all of them.

STUDY OF ELECTRICITY CONSUMPTION PATTERNS

The Monthly Load Factor has become higher for four of the customers, which means that the habits of electricity consumption have been improved. However, just one customer out of five has reduced the highest peak of consumption, so for the utility the profit from the change of tariff is negligible.

Semi-detached houses D and E are district-heating users, so they are not as weather dependent as the other customers. Nevertheless, their electricity consumption habits have not improved as expected.

SOLLENTUNA ENERGI CASE - RESULTS AND CONCLUSIONS

A general summary of the fifteen customers, highlighting the most relevant relationships among them, will be carried out in this section.

Relationship between Energy Consumption and Money Saved

As the study has shown, all the customers have saved money with the load tariff. The amount saved varied between 3% and 20%. Customers with the lowest consumption (flats) experience the highest benefits. Villas, with the highest electricity consumption saved the greatest amount of money, but not in percent.

The relationship between energy use and money saved for the different customers is presented in Figure 10.

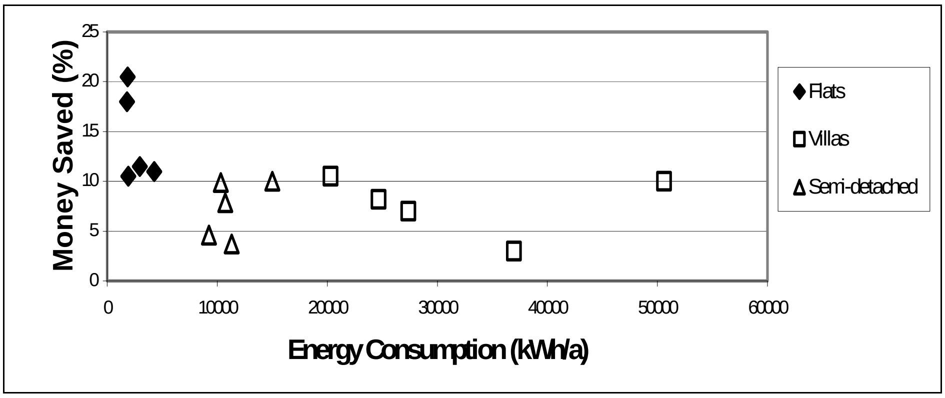


Figure 10. Energy use during 2001 versus amount of money saved with the load tariff expressed in percent.

Although there are some data points that do not follow the general trend, the figure above shows an inverse relationship between energy consumption and percent of money saved.

Relationship between Peak Ratio and Money Saved

The main objective of the new tariff is to lower the highest peaks of the year. In order to know whether this goal has been achieved, a new factor will be defined. This factor is called Peak Ratio and is calculated as follows:

Peak Ratio = Σ(20 highest peaks in 2000) / Σ(20 highest peaks in 2001).

If this factor results in values higher than 1 it means that the new tariff has worked for that customer, since the sum of the highest values of the year has been reduced.

Theoretically, customers with a Peak Ratio higher than 1 should be rewarded by the electrical utility. In fact, the higher the Peak Ratio the greater the reward provided should be. Actually, this does not occur as is shown in the following Figure 11.

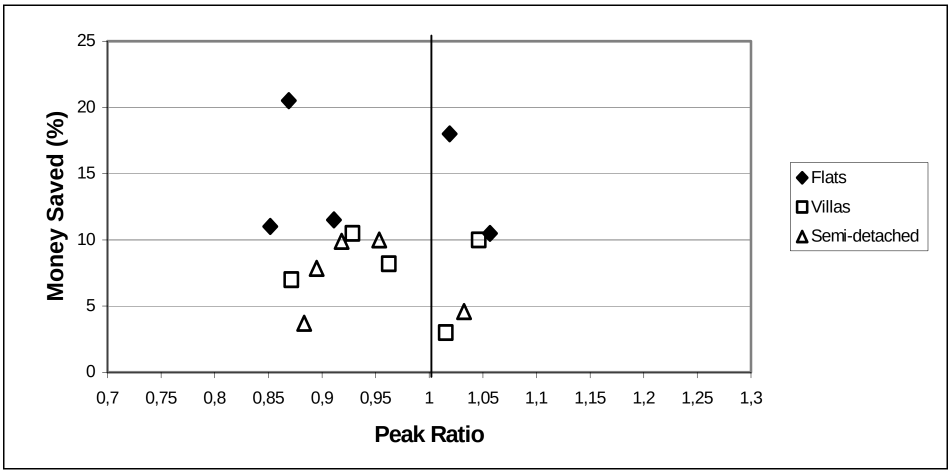


Figure 11. Peak Ratio versus money saved expressed in percent.

No relationships can be observed in Figure 11. This means that the new tariff does not work efficiently because it does not sufficiently reward those customers who have reduced their maximum peaks of consumption. Furthermore, all customers have achieved a reduction in their electrical expenses, but just 6 out of 15 have reduced their peaks of load demand.

Relationship between the Increase of the Monthly Load Factor and Money Saved

The meaning of this relationship is very similar to the previous one, but is considering the consumption during every month.

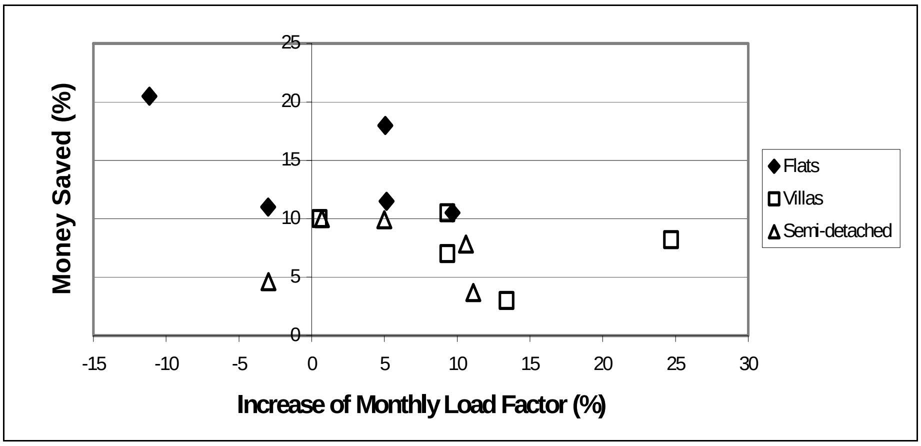


Figure 12. Relationship between the variation of LF_m and money saved.

The increase of the Monthly Load Factor will be expressed as a percentage and is calculated as:

$$\Delta LF_m(\%) = \frac{Average\ (LF_m 2001) - Average\ (LF_m 2000)}{Average\ (LF_m 2000)} * 100$$

Values higher than zero indicate that the consumption habits have improved. The improvement is greater the greater the percentage. Simultaneously, the economic benefit for the customer should be higher. The real relationship between these two factors is shown in Figure 12.

As Figure 12 shows there is no correlation between these two factors. On the other hand, almost every customer has improved the Monthly Load Factor.

CONCLUSIONS

The most important conclusions drawn from this study are as follows:

A load charge added to the tariff is expected to change customers' consumption patterns. Thus, this charge has to be constructed so that the price of electricity is a bit higher if there are no changes in the consumption behaviour and more expensive if the highest peak of consumption grows more than the energy consumption. Of course, customers' electrical expenses have to be considerably reduced if they are to significantly improve their consumption patterns.

It is very important to emphasise two aspects of the new tariff. The electricity price should not vary during the summer, since the utility has no problems then. Neither the saving nor the highest expenses should focus on the summer period. On Sollentuna Energi's tariff, one of the problems was that customers made such great savings during the summer period that they had more money to spend during the winter, thus neglecting the improvement of their electricity consumption habits.

The second point worth emphasising is that it would be very useful for the utility if the new tariff was supported by some tools of Direct Load Control. These tools would allow the utility to switch off either the customer's electrical heating or their boilers if the load demand is dangerously close to the limit contracted. That would be a powerful weapon for the utility, especially as it would not cost anything if it were not used. Customers' acceptance is very important for the utility, since it would give greater load demand control.

This case study should be followed by wider investigation for 2001 and 2002 with a behavioural study of electricity use patterns as a main part.

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III

DISTRICT HEATING EXPANSION STRATEGIES IN DETACHED HOUSE AREAS

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ABSTRACT

District heating is well expanded in the residential areas in Sweden, although not in detached house areas, where it is often impaired with problems of low heat density, large heat losses and high construction costs. However, due to the changes on the electricity market, increased environmental concerns and technological improvements, the detached houses' sector is a potential market for district heating.

The aim of this study was to find out what kind of strategies the Swedish district heating companies have for expansions to low heat density areas; what kind of information the companies gather about their potential customers; what facts they base their decisions on for selection of prospect areas and for marketing purposes; and what sales activities are used to obtain a high rate of connections.

To investigate these questions, a survey was sent to all district heating companies in Sweden. Questionnaires of the companies were followed up by telephone interviews.

The study concludes that the most important factor for choosing a new expansion area is the areas close location to the existing grid. Our analysis of the information collected by the companies about their potential customers proves that the customer basically is seen as a "heat load" in the system rather than an individual with different needs and interests. Promotion campaigns in detached house areas often include the phenomenon of social diffusion where the companies use interested potential customers to promote district heating. Specific sales strategies singled out deals to a large extent with solving timing problems when converting customers' heating systems. Value added services of district heating are rare.

Keywords: *District heating, expansion strategies, sales activities, detached houses, low heat density*

1. INTRODUCTION

The market of selling district heating to detached house areas in Sweden has not been considered a very interesting business until recent years, primarily due to low heat density, high heat losses, high construction costs and well developed competitive heating sources, particularly electricity, which is the dominating heat source for detached houses (Swedish Energy Agency, 2002). About 8% of the detached houses in Sweden are connected to district heating today (Swedish Energy Agency, 2003). The line heat density (defined as sold heat divided by the total pipe length in an area) in detached house areas normally varies between 0,5-2 MWh/m. The average value in Swedish district heating networks is about 3,5 MWh/m (Swedish District Heating Association, 2004). When the line heat density is lower than 2 MWh/m an area is denominated a low heat density area (Werner, 2003). In this study detached house areas are considered as low heat density areas.

Due to the latest years of increasing electricity prices, other heating alternatives are becoming more popular, and the possibilities of selling district heating to detached houses are increasing. Other factors, such as environmental concerns and technological improvements (for instance improved insulation and piping technologies) also encourage the expansion. Since district heating in Sweden is already well developed in high heat density areas the companies look for new markets and detached houses is a very significant one. Different companies have different prerequisites for expansion as well as different expansion strategies. The strategies need to consider technical, economic and social factors. It is essential to have high rates of connection in low heat density areas to make the expansion economically feasible.

The competitors to district heating in the detached house sector are not other district heating companies, but rather those companies who sell boilers and heat pumps, electricity and/or natural gas. Investments in district heating grids are just too big to build parallel grids. The product of district heating – to provide the customer with heat and hot water – is compatible, but not the same to the customers as the other alternatives. To differentiate the product from other heat sources the district heating companies should promote the competitive advantages of the district heating system, which would require knowledge about customer preferences and needs. A competitive advantage for retailers of heat pumps and boilers is the fact that they can do sporadic selling's to geographically spread customers. To get profit or even to reach break-even when building district heating in low heat density areas a high rate of connections to the grid is essential. Hence, the marketing of district heating to detached houses, means selling to a selected group where ideally everybody in the group will buy.

The change of heating system in a house is a matter of timing. The existing equipment should either be old or in a need to be exchanged, or there should be some other beneficial factors in changing the system. From the customer perspective, the change of heating system means a high involvement decision. A new system is costly and the conversion requires many changes in the building.

Though economic issues are obviously important when choosing heating systems, research has shown that customers should not be seen as economically rational decision makers, as they have a need to simplify their choices and therefore they focus on just a few preferences and consequences and disregards others (March, 1994). For that reason it could be wise to offer a set of different economic propositions in order to adjust to customer needs. Personal situations may occur in the household that makes the household members less apt to do any larger changes in the house, for example if the household members are old, or if they are planning to move in the near future. The main conclusion from this reasoning is that in order to connect as many households as possible within a specific area, the customers should be viewed as a heterogeneous group with different needs, preferences and knowledge.

The aim of this study was to investigate Swedish district heating companies considering:

- How they select prospect expansion areas and what facts they base their choices on
- What information they gather about the customers and how they collect it
- What sales activities they perform to obtain a high connection rate in prospect areas

2. METHODOLOGY

2.1. The survey

This study is based on a survey sent out to all members of the Swedish District Heating Association (SDHA). These companies supply 99% of the total district heating sales in Sweden. The frequency of response was 30% (51 companies out of 150). The survey questions aimed to cover the following information about the companies:

- Background information about the company and its heat production/sales
- Performed expansion to low heat density areas
- The company's information about customers
- Sales activities

In order to deepen the answers regarding the expansion strategies telephone interviews were carried out with 17 of the respondents.

2.2. Applicability and generalization of the survey results

The study is limited to investigate the sales strategies of Swedish district heating companies and survey data stems from answers of representatives from the SDHA companies. Customer surveys are not carried out. Since essentially all Swedish district heating companies are members of the SDHA one can say that the Swedish district heating companies are well represented in the study. The falling off of respondents might naturally distort the results and a comparison with statistics that include all SDHA members has therefore been performed. The analysis shows no large discrepancies from the sample population in terms of ownership structure, annual heat sales, share of heat sold to detached houses and fuel mix.

3. RESULTS AND DISCUSSION

3.1. Decisive factors for expansion in low heat density areas

Building district heating systems in low heat density areas is economically challenging. Considering this, it is of interest to investigate what factors the district heating companies find essential when they decide whether to expand into a low heat density area or not. The survey results are presented in Figure 1.

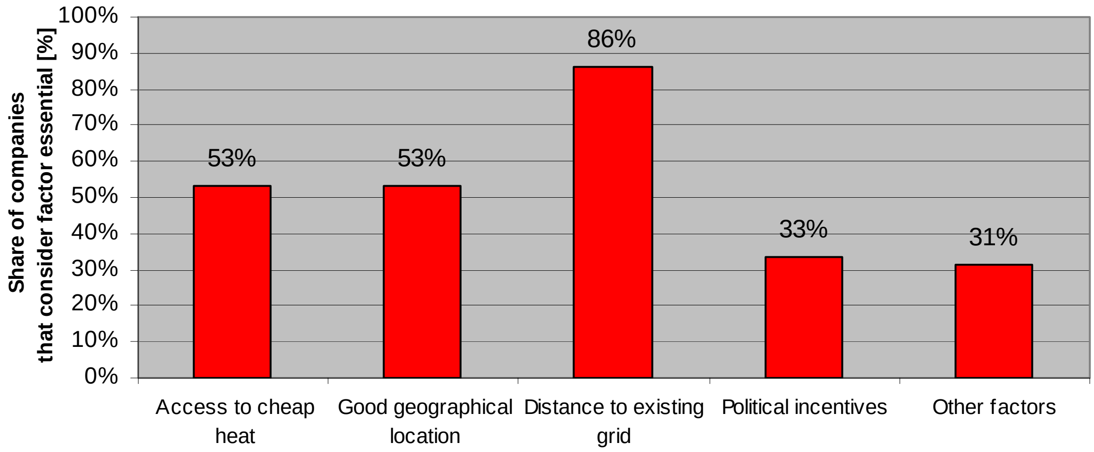

Figure 1: Factors that district heating companies find decisive when expanding in low heat density areas

According to Figure 1, approximately half of the respondents find access to cheap heat to be a decisive factor when expanding into low heat density areas. This relatively low value is actually surprising since low production costs can be expected to be an essential factor for expansion. One possible explanation could be that many companies view the heat production as something almost invariable and therefore they have a vague picture of what the situation would be like if they, for instance, had access to cheap waste heat. The most important factor when district heating companies decide whether to expand into an area is its location in relation to the existing grid. Many companies have commented that only detached house areas located close to existing mains are connected to the grid. With "Good geographical location" the distance to the production site, ground conditions etc was intended, however it turned out that many respondents thought that also this alternative was related to the distance to the existing grid. Considering that a majority of the Swedish district heating companies are municipally owned, it is not surprising that one third of the respondents specified that political incentives are important. Commonly specified examples of political incentives were measures to limit local and global environmental pollution. As "Other factors", for instance over-capacity in the production, grants to the district heating companies for expansion and grants to private persons for converting to district heating were mentioned. However, the opinions differ regarding the importance of grants; some companies find them to be important while others think they are quite insignificant.

3.2. Information about customers

To be able to know who your potential customers are within the chosen expansion area, you need to have information about the houses and the people living in the area. This study investigates how the district heating companies gather information, what kind of sources they use and what kind of information they collect. In Figure 2, results from the survey regarding which sources district heating companies use to obtain information about the potential customers are put together.

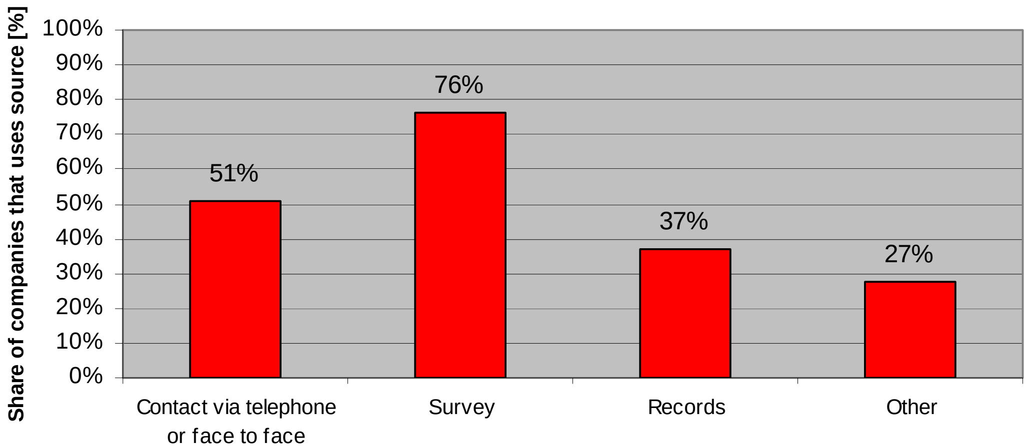

Figure 2: Sources of customer information used by district heating companies

As seen in Figure 2, the most common source of information about potential customers is customer surveys. Surveys sometimes are sent out to all households of detached houses in a city but most often only to households within a selected area. Half of the companies' say that they make personal contact with the potential customers either face to face or via telephone. About one third of the companies state that they use records or directories of different kinds. One example of this is the municipal energy plan, which has to be approved by the municipal council. The energy plans are thus established documents that show the visions and objectives of future energy supply and energy use in the municipality. Property taxation directories are also mentioned as information sources. Here some interesting information can be found about the properties in a selected area. Another useful record stems from the fact that in Sweden, well-boring for installation of energy wells must be reported to the authorities. A few district heating companies mention that they sometimes use this record to map out the presence of heat pumps in an area. Other sources of information can be local craftsmen, for example plumbers and chimney-sweepers. A big advantage with these professionals is that they not only can tell what kind of equipment the households have, but also what condition these are in.

The next question is: What information about the customers are the companies interested in? Figure 3 displays what information the companies state that they collect about their potential customers based on alternatives given in the questionnaire.

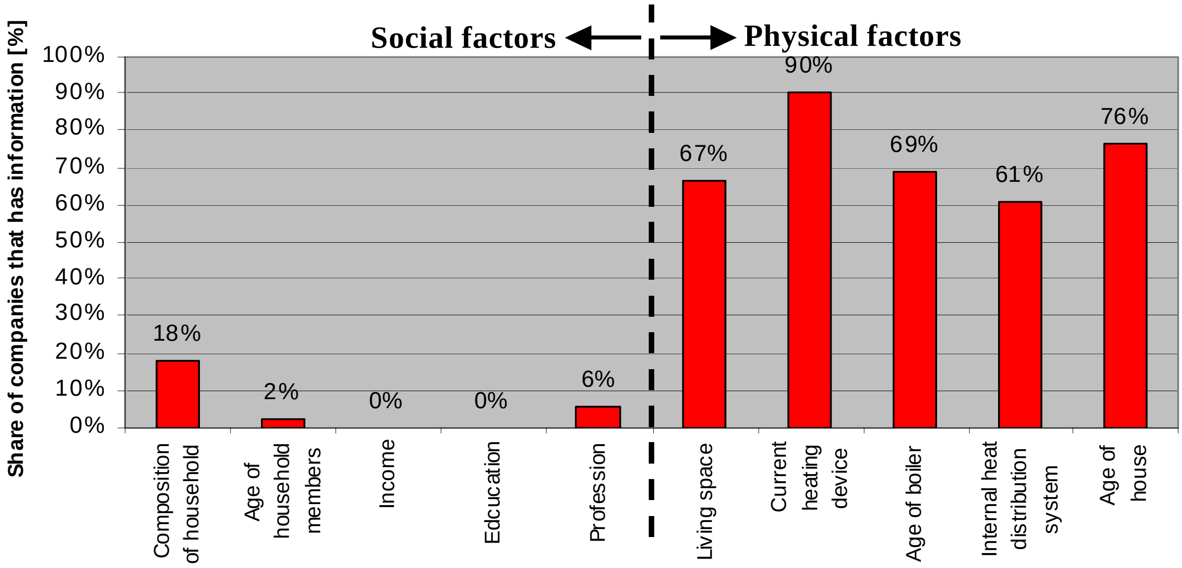

Figure 3: Facts about potential customers

According to Figure 3, the district heating companies have a clear insight in most of the physical factors that can be of interest when estimating the heat demand in an area. They also have pretty much information of the customers' present need to shift heating systems and if the internal heating system has to be rebuilt in order to connect to district heating. Social factors like age of household members, income, profession and education, are hardly examined at all. One exception is the composition of the household, where 18 % of the companies state that they gather this kind of information. However, this can be due to the fact that the number of household members could be one of the factors for estimating domestic hot water load.

The chart in Figure 3 gives a clear picture that the Swedish district heating companies to some extent still view their customers mainly as subscribers for heat rather than customers with different preferences and needs.

3.3. The sales process

In Figure 4 the typical course of action that district heating companies use when expanding into detached house areas is shown. The summary is based on the survey and the interviews.

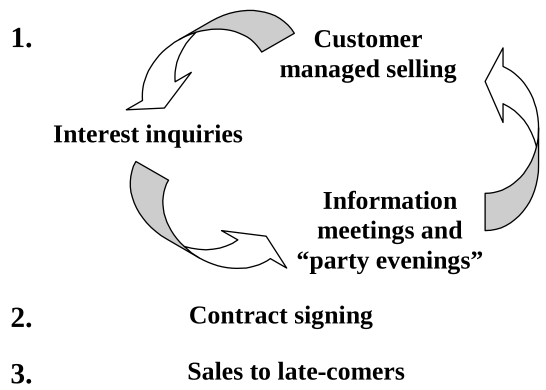

Figure 4: District heating sales process in detached house areas

It is often the case that customers initiate the contact with the company wondering when they will be able to connect to the district heating system. Often these interested customers act as the company's "ambassadors" and play an important role in the selling process by investigating interest and promoting district heating in the specific area. In other cases the company, based on available information or due to shown customer interest, selects an area they believe have a potential. Once an interesting area is found, interest inquiries are sent out and/or information meetings are arranged. The purpose of these activities is both to provide the potential customers with information and to gather information about them. If the interest in the area is high enough the next step is contract signing. The contract is typically a unilateral agreement where the customers commit to connect to the district heating system if the company decides to go through with the project. The company on the other hand normally makes no commitment to the customer at this stage. During or even after the construction process, efforts are sometimes made to get more customers to connect to the grid. The fact is that some customers tend to decide to go for district heating only after the construction has started. A possible explanation to this can be that the customers are uncertain whether there will be an expansion or not and that they want to see if the expansion plans really are to be realized. Another explanation can be that in the course of construction, the customers have the possibility to meet and talk to representatives from the district heating companies.

3.4. Strategies for dealing with timing problems

When a new district heating grid is being built some customers might not have the interest or means of getting connected. For example, they might have just invested in a new heating system or they don't have the money to put in to the investment at the present time. Some of the district heating companies in the study came up with strategies to deal with timing problems when converting the customer heating systems:

- **Customer compensation for current heating device:** Some companies pay for the customer's old equipment in order to attract those customers who recently invested in a new heating system. The compensation is often restricted to an age limit of the equipment.
- **"Heat emergency":** Sometimes customers have problems with their old boiler before the district heating grid has been fully constructed and they can connect to it. To help the customer – who has already signed the contract with the district heating company and therefore is not interested in another new system – the company can offer to install a heating system to operate until the connection can be made. Some companies use old boilers they have bought from other new customers. A few companies have come up with the solution to install the district heating substation that will be used, but to use it temporarily with an immersion heater. The cost for the heat during this temporary solution sometimes is adjusted to district heating prices.

- **Mediation of boilers:** Another example to facilitate customer change of heating system is to help mediate old boilers to other buyers.
- **“Resting connection”:** If the customer for some reason don’t want to connect to the district heating grid immediately, some companies offer a “resting connection”. This means that the pipes are drawn to the customer facility, even if the customer does not buy heat. Different companies have different agreements on time limitations and connection fees. In some interviews there has been companies that strongly oppose the use of resting connections due to problems that occur when the customers choose never to connect to the grid.
- **Repurchase of oil:** Some examples exist of companies that offer to purchase the remaining oil in the customer boiler tank. This offer could of course be extended to include other types of fuel.
- **Competitive pricing:** Some companies choose to subsidize the connection fee in order to make the financial part easier for the customers. In this way, customers with small possibilities to take out mortgages on the house or that suffer from a temporarily bad economy, still can afford to make the connection to the district heating grid. If the energy price for district heating is considered to be substantially lower than for other alternatives, this also can have an impact on the household’s immediate living expenses.

3.5. Experiences and advices

Both in the survey and in the interviews, recommendations and ideas came up regarding sales in detached house areas. A common idea is that interested customers should be used to investigate the interest in their neighbourhood. Often one or a few “ambassadors” for district heating will appear and these can carry out the initial work in the sales process. In this way the company can avoid putting sales effort into areas where the general interest in district heating is low. One interviewee expressed that “the best salespersons of district heating are the house-owners themselves”. It is apparent that the influence of social diffusion is important. For instance, one interviewee had the opinion that May to August are the best months to sell district heating. During this period most Swedish house-owners spend lots of time in their garden and thus there will be many occasions to discuss for instance district heating with the neighbours. However, it should be remembered that the competitors to district heating also have “ambassadors” and they can in a similar fashion ruin the market for the district heating company.

Some interviewees had thoughts regarding how to act during and after the interest in an area have been investigated. One thought was that if the number of customers is not great but at least sufficient, the expansion plans should be realised. The idea of “the excavator as entrepreneur” was introduced meaning that once the building process starts there will often be more customers who decide to join. Apart from this, some condensation of the system will hopefully occur even after the initial expansion. If the interest is so low that the company, despite great sales efforts, cannot go through with its expansion plans, the specific area should be considered as “lost” for a considerable time. The reason for this is that the need to replace the current heat source is a real need for many of the house-owners. If they were not aware of this need earlier they certainly will be after the marketing from the district heating company. Hence, if the new heat source cannot be district heating, then the house-owners will look for alternatives making it even harder for the district heating company to attract more customers in the specific area at a later stage.

Different customers have different economic situations. One company that has taken this into account is Göteborg Energi AB. They offer their customers three different types of contracts of district heating with alternative investment cost for the customer, yearly price and energy price, see **Fel! Hittar inte referenskälla.**.

Table 1: Contract alternatives for detached house owners Göteborg Energi AB, (Magnusson, 2004)

Contract name	FV 1*	FV 2*	FV 3*
Investment by customer [SEK**]	0	31000	82000
Yearly price [SEK]	3900	0	0
Energy price [SEK/kWh]	0,748	0,748	0,50

*Vat is included in the prices
**1 SEK ≈ 0.11 EURO

The company expected alternative FV 1 to be the least economically beneficial choice for the customers. 70 % of the customers, however, choose this alternative, 20 % choose alternative FV 2 and 10 % FV 3 (Magnusson, 2004). Even if the company didn't know their customer preferences very well, the variance in customer choices shows that the different alternatives appeal to different customers. By offering alternatives, the company better adjust to customer preferences.

Based on the surveys it is apparent that most selling strategies used by the district heating companies today disregards factors besides the core product "to sell heat to detached house customers". To be able to differentiate the product from what the competitors offer, district heating companies could offer value added services. The customer might not just need a new heating system; to have a snow free garage drive or to get a landscape gardener to help organize the garden when the pipes have been installed are examples of customer focused services which you rarely see in the marketing strategies of the Swedish district heating companies. Even if there is a rather big interest amongst house-owners in detached house areas to connect to the district heating grid, there is still the matter of getting a high rate of connections. The information that the companies have stated that they collect about their potential customers is not of the kind from which you can develop specific solutions for specific customers.

4. CONCLUSIONS

- A high rate of connections is essential in selling district heating in low heat density areas. Many companies state that they experience a great customer interest in district heating and that they often get phone calls from customers who want to connect to district heating. Thus the problem is not to get interested customers but to get as many customers as possible to connect within a prospect area.
- Closeness to existing district heating grid is the most important factor when choosing expansion area according to the companies.
- The fact that the kind of information companies collect about potential customers mainly refers to technical factors and not to social, implies a somewhat rigid view to the customers. Without social information about the target group it is very hard to offer tailor-made solutions to the customers.
- Some companies have come up with sales strategies that incorporate strategies of timing problems. These strategies may facilitate the customer situation when changing heating system.
- Many companies are aware of the importance of social diffusion and use it to different degrees in the marketing process.
- Most selling strategies used by the district heating companies today disregards factors besides the core product "to sell heat to detached house customers". Solutions to other customer needs could give value-added service to the customers. More creativity is desired.

5. ACKNOWLEDGEMENT

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IV

Turn Me On, Turn Me Off!

Techno-Economic, Environmental and Social Aspects of Direct Load Management in Residential Houses

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Keywords

Direct load management, load problems, residential houses, electric space heating and hot water systems, customer perspective, utility perspective

Abstract

Load management is a techno-economic measure for harmonizing the relations between supply and demand sides, optimising power generation and transmission and increasing security of supply. It can also benefit the environment by preventing use of generators with higher emissions.

This study was performed in collaboration with one electric utility in Southern Sweden, which aims solving peak load problems either with load management or by constructing diesel peak power plant.

The objective of the study was to experimentally test and analyse the conditions and potential of direct load management from customer and utility viewpoint. Techno-economic and environmental aspects as well as customer experiences were investigated.

Ten electric-heated houses were equipped with extra meters, enabling hourly load measurements for heating, hot water and total electricity use. Household heating and hot water systems were controlled by the utility using an existing remote reading system. The residents were informed about the experiment but not about the time and duration of the controls. The experiment was followed up by interviews.

According to the interviews, the residents noticed some of the control periods of heating. Body activity level as well as compensation of sun radiation and heat producing appliances influenced the experiences. After the experiments the households were positive about load control, but they expressed requirements for the implementation of such measures.

The experiments proved that direct load management might be a possible solution for the utility to solve its peak demand problems. The potential hourly load savings for heating varied from 1,1 to 3,8 kW per household.

Introduction

Load problems and load management

Load demand is an important techno-economic issue both for electricity producers and for grid companies. Load problems can occur due to fall in production or the limited transmission capacity in the grid.

The liberalization of electricity markets brought up new problems both in Sweden and in many other countries - many energy generation plants have been decommissioned or preserved for economic reasons and the earlier excessive electricity production capacity has been reduced substantially. This process has however increased risk of notable load problems in the electricity systems.

Load management is defined as a set of objectives designed to control and/or directly or indirectly modify the patterns of electricity use of various customers of a utility to reduce peak demand. It is not - as one may think - a measure to save energy, but to run the power supply system more efficiently. Power is not saved but the load demand is moved from peak hours to times with lower coincident load. Depending on what production mix is used at peak hours, load management might help to reduce the use of power generation plants with relatively higher emissions (such as oil condensing power plants and gas turbines). Expansion of the electricity network might also be avoided due to load management. Table 1 lists different economic, technical, environmental and social interests in using load management measures (Abaravicius, 2004).

Table 1. Summary of interests in load management at customer and utility sides

	Customer	**Utility**		**Producer**	**Grid operator**	**Society**
		Retail company	**Network company**			
Technical	Avoiding fuse problems		Avoided network capacity problems	Maximum use of base (and cheapest) production units Avoided production capacity addition	Stable operation of power system on national level	Stable operation of power system on national level
Economic	Lower electricity costs Lower network costs due to lower fuse level	Lower risk when purchasing power on spot market	Lower demand subscription fees. Avoided investments in the network	Lower production costs	Stable operation on lowest costs Avoided/postponed investments in the network	Economically sustainable electricity supply. Maximum reliance on local production
Environmental	Avoiding peak power plants nearby living area	Fulfilling goals established by environmental certification programs	Fulfilling goals established by environmental certification programs.	Avoided use of peak units (e.g. diesel or gas turbines) – which result in high emissions	Avoided new network construction	Least possible environmental effects
Social	Service compatible with the social activities					Power accessibility and equal conditions for all members of the society

Load demand in residential sector

The residential, commercial and service sector accounts for half of the total electricity consumption in Sweden. Electric space heating currently accounts for just over 30% of the total electricity consumption in the sector. Approximately 104 TWh of heat was used in 2003 to heat homes and premises, of which district heating accounted for 45 TWh and electric heating for 21 TWh (Swedish Energy Agency, 2003). High electric load demand variations therefore occur in winter season following outdoor temperature variations. The increased number and the variety of household equipment also cause risks for load shortages if used simultaneously. Even in households with an alternative heating and hot water systems (district heating or natural gas), hourly load demand reaches very high values. Load demand in the residential sector varies significantly during a day and normally has peaks during morning and evening hours.

Detached residential houses in Sweden comprise a large part of the residential building stock. The dominating energy source for heating and domestic hot water for these houses is electricity. Under current dominating pricing conditions (tariffs, etc.) in Sweden the customer is not encouraged to use load optimally. However, the electricity suppliers, having already to a great extent used the load management potential in the industrial sector, consider the residential one as a significant potential for load management. There are several examples of direct load management systems, used in residential houses both in Sweden and other countries. The division into network and retail companies, as a result of the liberalization of the electricity market, has complicated the situation because normally the grid companies own those systems.

Two of the largest Swedish electricity suppliers, Vattenfall and Sydkraft have performed load management projects in detached houses. For example, Sydkraft project “ToppKap”, performed at the end of 1980s and the beginning of 1990s focused on developing an electronic load control system for direct resistive heating. The performed tests showed the potential of load decrease of 4 kW per house (at -13 °C) with minimal comfort losses for the customers (Sydkraft, 1989). Vattenfall project “Uppdrag 2000”, performed in 1990, was focusing on controlling electric boilers in small houses with waterborne heating systems. Average load savings achieved under cold winter days were about 3 kW per household. Many problems, however, came up with recovery load (load demand to reheat the house after the control period – which causes another peak) in those experiments (Levin, 1993). These projects were basically focused on techno-economic performance of the control system and the potential of load demand reduction. Analysis of the consequences for the residents included only indoor temperature drop measurements during control of heating and the residents’ experiences during the system installation phase. Neither the customers’ view of their heating and hot water comfort nor their opinion and acceptance of load control was analysed.

Associated utility and its load problem

In this paper, the use of load management at a local level, in a specific case of a Swedish utility, Skånska Energi AB is investigated. The utility is located in the south of Sweden, Skåne, and has 16 500 customers, of which 99 % are residential customers that account for about 53% of the electricity sale. Skånska Energi AB comprises two subsidiary companies - the grid company Skånska Energi Nät AB (SENAB) and the trading company Skånska Energi Marknad AB. An advanced metering system “CustCom” is installed to all Skånska’s customers. The system provides automatic hourly measurements, as well as load control and information services.

Load problems at the utility occur during peaks in wintertime, usually on weekday mornings and holiday (weekend) afternoons. Load demand in the utilities grid is especially sensitive for weather changes, as the majority of Skånska Energi’s customers have electric space heating. Daily peak demands (during morning and evening hours) together with higher heat demand due to outdoor temperature drop, cause risk to exceed the subscribed load for the grid company. This results in penalties from the higher level network owner Sydkraft, and thus significant economic losses. The utility would benefit economically by securing the load below the subscribed level and by decreasing it. In year 2002 and 2003 the subscribed load was 76 500 kW.

The utility has some few alternatives to solve this economic problem:

- To apply direct load management using a remote metering and control system CustCom, installed at the utility,
- to introduce a new pricing with a load demand component, or
- to install diesel peak power plant with 2-3 generators with a capacity of 4 MW each.

The construction of the peak plant would have negative environmental impacts both on local and global levels. First of all, the plant has to be located close to the users. This might create significant problems in local environment, as the quality of the environment would be decreased both by emissions and possible noise level increases. From the global perspective, the production of electricity using diesel generators would mean high CO_2 emissions. The efficiency of such a technology is low and the resulting emissions are high. Diesel generation normally has the lowest generation efficiency, reaching only around 25% and also one of the highest emissions factors per fuel, reaching 288 kg C/MWh (1056 kg CO_2/MWh) (Meyers, et al). For the comparison – the average CO_2 emissions from electricity production in Sweden is 12 kg CO_2/MWh. If the utility would implement load management measures instead of building a new peak power plant, this would obviously be a better solution from the environmental perspective.

Load management has to be tested in order to investigate the load control system's techno-economic performance. Also, customer's experiences on indoor and hot water comfort has to be analysed when controlling heat and hot water in the customer's houses, as well as the customer's attitudes toward this kind of encroachment made by the utility in the home.

Objective of the study

The objective of this study is to experimentally test and analyse the conditions and the potential of direct load management in 10 residential households with electric space heating and hot water systems. The study aims to consider both customer and utility perspectives and to cover not only techno-economic but also social aspects of load management.

From a techno-economic perspective the study aims to analyse the technical performance of the control system and customer's equipment, load savings, recovery load, and management costs. From a social perspective – the customer experiences and attitudes influence on indoor climate and social activities as well as control limitations are the primary focus.

Methodology

10 pilot households

Ten households (in this study called H1…H10) in Södra Sandby, Southern Sweden were selected for a load management experiments. All of them are the customers of Skånska Energi and have electric space heating and domestic hot water systems. The selection was based on the energy survey, performed by the research group in year 2001. The households were asked if they would agree to participate in energy experiments. Of those answering in the affirmative, ten households were selected.

The number of residents is: one person in one household (H3), two persons in five households (H1, H2, H4, H5 and H6), three persons in three households (H7, H8, H9) and four persons in one household (H10). Seven of the analysed houses are detached houses and three are semi-detached houses. The houses are of similar age, since all were built in the period of 1964-1978. Some of the houses (H2, H3, H4 and H9), were extended in the later years. The living area varies from 95 m^2 to 300 m^2. The houses are also of different design (one to two storeys). One of the houses (H5) has a basement, which is used as living area. The dominating construction type of all houses is brick with wooden frame or light concrete frame. In most of the houses the attic insulation was improved after the construction. Four of the houses (H1, H2, H3, H4) have waterborne space heating systems with electric boiler, while the other six (H5, H6, H7, H8, H9 and H10) have direct electric resistive heating. H2 in addition has a heat pump. Electric water heaters work as separate units in all of the houses except H2 and H4 where these are integrated in the boilers.

Metering

The load and outdoor temperature data was obtained via the CustCom system. Total hourly electricity use is normally measured and stored in a database. Two extra electricity meters were installed to measure the load demand for space heating system, and for water heaters in the analysed households. Metering of heating and hot water loads for all selected households started on April 1, 2003 and continued until February 15, 2004. In two houses with waterborne space heating systems (H2 and H4) it was technically impossible to separate heating and hot water load.

An indoor temperature logger was mounted on the inner wall in the living room in every household at about 130 cm from the floor. Temperature readings were logged every 15 minutes with a precision of 0,5 °C during the test period. Since only one logger was used in each household, the rough assumption is that the temperature is the same everywhere in the house.

Load management experiment design

Experiment period, duration of control periods, time of day and forecasted outdoor temperature were factors that needed to be considered when designing the experiment.

The experiment strategies were developed based on the analysis of available measurements and considering both the utility perspective and the household perspective. From the utility perspective, the control periods were adjusted to the times when the utility usually would have problems – few peak hours on weekday mornings and holiday (weekend) afternoons. From the customer perspective - the control time was limited from 1 to maximum 4 hours when controlling heating in order not to deteriorate the customers' comfort too severely.

Before the experiment started, the households were given a prepared form to make notes about changes in indoor climate and in hot water comfort. The household members were also asked to note times when nobody was at home. The reason for this was to see if the residents missed out on some of the load controls. These notes make a clear indication on whether the controls are noticed or not, since the residents' experiences in this way are stipulated in time and afterwards can be compared with the actual control schedule.

The experiment was carried out during period of three weeks Feb 16, 2004 – Mar 7, 2004. Customers were not informed about the exact experiment periods in order to discover if the control periods were actually felt by the customers. The essence of the experiment was on/off control of space heating and hot water systems in houses according to the schedule prepared by the research group and sent to the utility. The utility personnel set the control for the given channels in the CustCom system. Load for space heating was switched off for the periods of 1, 2, 3, 4 hours and load for hot water was switched off for the periods of 1, 2, 3, 4 and 16 hours.

The time, chosen for the experiment was within the statistically coldest period in the region. Nevertheless, relatively high outdoor temperatures this particular year did not allow to make the tests under the most sensitive conditions. (Hourly outdoor temperature data for one place, at Skånska Energi headquarters area, is also provided via CustCom system.)

Load control method

The architecture of a complete CustCom system (see Figure1) typically incorporates three main items: individual customer terminals (counters), intermediate stations (collectors) and a central controlling unit (commander) located at the utility. Two-way communication signals transmit the information between the customer's terminal and the utility by the use of either radio, GSM, fibre or control cable. The information that is transmitted includes meter readings, various control signals and additional features such as alarms (North, 2001).

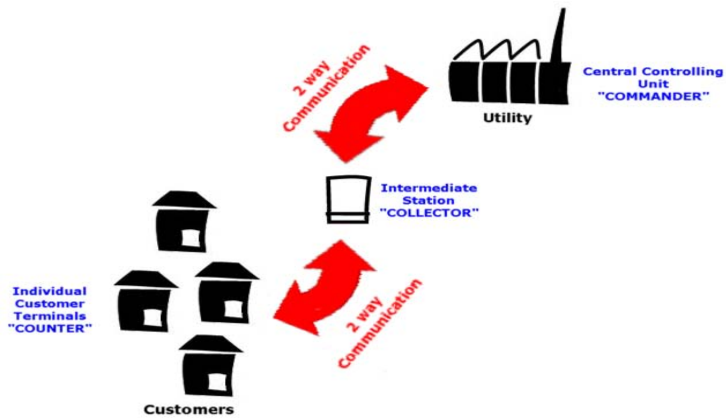

Figure 1. CustCom's typical system architecture (North, 2001)

The CustCom system provides several technical possibilities to control load. One of them is "object control", which was used in this experiment. The Counter 1000, one of the constituent units of the CustCom system, was extended with an additional card, which created the possibility to control load for specific devices (objects). These additional load control cards and extra relays were installed by Skånska Energi in all the ten houses.

Interviews

Immediately after the test period, interviews were carried out with the household members in the ten houses. The interviews were typically semi-structured interviews with opportunities for the household members to talk about different themes decided by the researcher. The themes covered:

- Residents experiences of the on/off regulation of heating and hot water, that is indoor climate and changes of hot water comfort during the test period
- Experiences of the normal indoor climate and hot water comfort
- Thoughts about energy use in the household
- Opinions of load management measures; how would these measures have to be designed in accordance with the interviewees' requirements?

The interviews took place in the respondents' home and lasted for 45 to 90 minutes. They were recorded and subsequently transcribed. Both interview answers and notes about changes in indoor climate and hot water comfort were later analysed together with the indoor temperature data in order to compare the physical temperature changes with the residents' experiences of the indoor climate.

Results

Techno-economic aspects

Performance of the control system, load demand savings, recovery load and costs are the major techno-economic parameters considered by the utility.

Load demand savings for space heating

Load savings for heating are calculated in the following way:

$$LS = \frac{P_{bc} + P_{ac}}{2}$$

Where:

LS – Load savings

P_{bc} – hourly load before the control period

P_{ac} – hourly load after the control and recovery period (it is assumed that the recovery load period lasts for one hour after 1-2 hours of load control, or 2 hours after 3-4 of load control. The assumption is made based on actual readings of load curves)

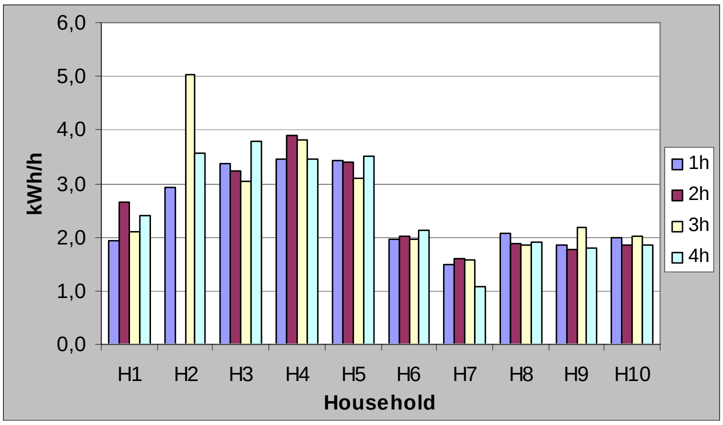

Figure 2. *Average hourly load savings on heating (In H2 the 2-hour control was not performed)*

Figure 2 summarizes the results for all households and shows that H2 and H4 have highest hourly load savings on space heating. It is important to consider, however, that the data from H2 and H4 also includes load for hot water, since these houses have boilers with integrated hot water system. The results for other households show that the savings in principle depend on house area. H3, H5 and H1 have larger living area and thus larger demand for space heating than the remaining ones. Households 6, 7, 8 and 10 have "soft heating" systems and load guards that keep the load demand below a specific level. The basic feature of "soft electric heating" system is the pulsing of the electric energy to the specific radiators in specified time intervals. Since the pulses are shifted, the radiators are never switched on all together, which decreases the load demand.

The potential hourly load savings for space heating varies from 1,1 to 3,8 kW per household, which is a similar result as obtained in previously described studies carried out by Sydkraft and Vattenfall. As it can be seen the potential load savings are lower at the households with "soft heating" systems.

Recovery load for heating

Recovery load occurs when the system is reheating the house after the control period. It is an important issue since it can result in another, even higher, peak after control, which, in turn can cause problems for the utility and customers. Figure 3 shows the recovery loads for space heating after the implemented control periods (during the first hour after the control period). A dependency on the duration of the control period can be observed here

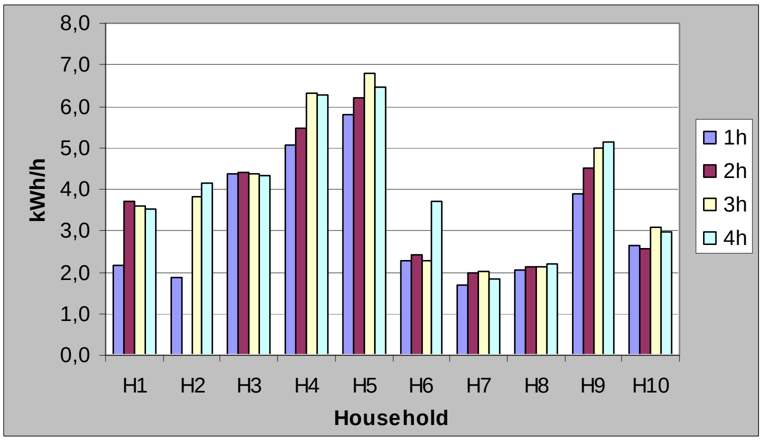

Figure 3. *Recovery load for heating*

Households 6, 7, 8 and 10 have "soft heating" systems and load guards, which is reflected in the recovery load levels for those households. This system can be recommended as a good solution to protect the grid from high recovery peaks. For the household it could mean a longer deterioration of indoor comfort, specially during more extreme winter weather conditions. In this particular experiment the indoor temperature drops were very small as the outdoor temperature was relatively high.

Load savings for hot water preparation

Domestic hot water systems have a potential for load savings (for 1 – 4 hours control) without serious negative consequences. However, it is difficult to say how big the savings are, as water use measurements were not performed in this study. The water heaters normally have installed capacities of 3 kW, which actually could be considered as a maximum switchable load.

An interesting question when analyzing hourly load control potential for hot water, is when the water heaters are on full power. Having this knowledge it is easier to create load management strategies, as it gives a suggestion when to control the heaters in order to get a maximum load savings. Using the daily load curve and the hourly data, the following methodology for finding the probability if the water heater is on full power was developed:

It was assumed that heater is on full power if its hourly load exceeds 2,5 kWh/h (exception was H7, where the maximum load is limited. In that case the assumed value is 1,5kWh/h). Every hour of the day through the period April 1, 2003 – February 15, 2004 is analysed. Number of hours when the full load value is reached is divided by the total number of recorded hours. The results show that the pattern of load demand for hot water varies from household to household, presumably depending on the behavioural factors. There is a tendency, though, that the highest demand occurs during morning and evening hours, therefore these periods could have the highest potentials for load control.

Measurements and control costs

When it comes to economic issues, the costs for extra equipment for measurements and control purposes (meters, relay, control card, labor, etc.) appeared to be relatively high, reaching 1100 EUR per household.

Would it be economic for the utility to implement direct load control? Some few rough estimations can give us an indication about it:

There are two reasons to implement load control: to avoid penalties and to decrease the subscribed load level. Penalty differs on weekdays and weekends - it is twice as higher on weekdays. If a subscribed load demand is exceeded, for instance, on weekday morning (a typical time when the utility risks to exceed the demand) by 3000 kW during one hour, the total penalty for the utility would reach 117 000 EUR. If, the utility would implement the control measures in 1000 households, assuming that average expected load saving is 3 kW/house, the penalty could be avoided. Additionally, expected savings for decreased subscribed load by 3 000 kW would be 88700 EUR/year. The installation in 1000 households, however, could cost around 1 090 000 EUR.

In year 2002 there was 1 hour exceeding of contracted load with 355 kW. In year 2003 there were no exceeding. In year 2004 there were three hours and exceeding was 3887kW, 3021kW and 1107 kW respectively.

From the technical point of view, the system CustCom proved to be a good technical tool to implement load control objectives. Few technical problems though were recorded during the experiment in some households (communication problems, fuse went off, circulation pump stopped), but it is not evident that the control actions was the reason for these problems.

Social aspects

Indoor comfort

Thermal comfort is, according to the standard ISO 7730, defined as “that condition of mind which expresses satisfaction with the environment”. Physical measurements of thermal comfort are thereby not practicable but to ask users about their opinions about the thermal comfort (Bengtsson, 2003). In this study, the indoor temperature as well as the residents’ perception of the indoor climate is considered.

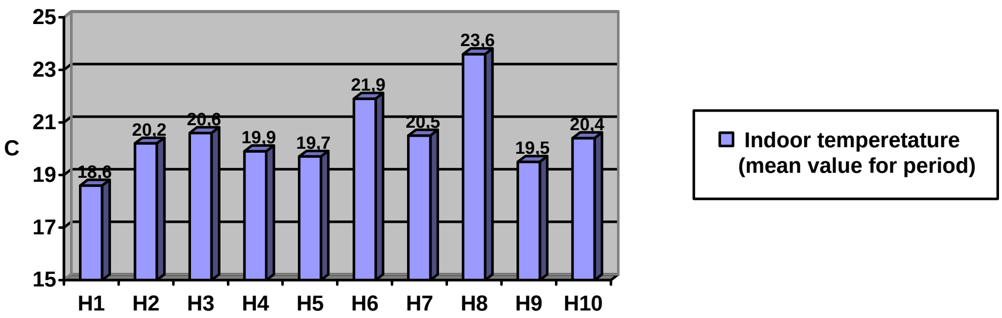

Figure 4. *Average indoor temperature in the ten houses during the test period*

The average indoor temperatures for the three-week period differ a lot between the ten households. In Figure 4 we can se that temperature levels differ between 18,6 °C to 23,6 °C. When asked in interviews, it is evident that some households like to keep the temperature low while others prefer to keep a much higher temperature in their homes.

Turning off the heating for 1,2, 3 or 4 hours naturally means that there will be an indoor temperature drop that depends both on the length of the period that the space heating is switched off and on the outdoor temperature. Figure 5 shows the result of indoor temperature drop in our experiment.

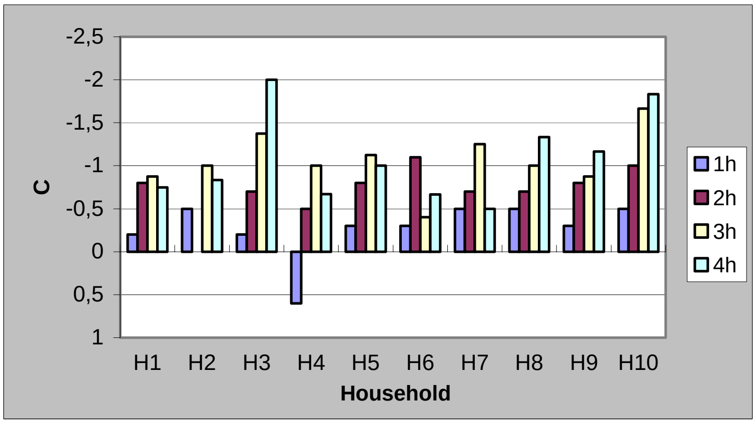

Figure 5. *Average indoor temperature drop due to the switch off of the households heating systems*

The Figure 5 is showing moderate temperature drops due to the switch off of the space heating system. For longer control periods the temperature drops reached down to 2,5 °C at most, but in general the temperature drops were lower. Radiation from the sun through the windows, as well as activities in the household including use of electricity (for example cooking), seem to have compensated for the temperature drops in some control situations. The outdoor temperature for the test period was relatively high for the season, between –0,8 °C to 6,1 °C (in average 2,1 °C). A lower outdoor temperature would most likely have resulted in larger indoor temperature drops when turning off the heating system.

Now, knowing the indoor temperature drop during the test period, how did the residents react to the temperature changes? Household notes from the test period show that some of the controls went unnoticed because the residents were simply not at home. For controls where people were present at home, many controls actually has been noticed and noted on the “comfort sheets”. These show that some households noticed the controls more than others. One interesting result is that the households with generally higher indoor temperature are as sensitive to indoor temperature drops as the others. Although a temperature drop from 23 to 22 degrees doesn’t constitute in a low indoor temperature level, these households have been able to detect the change in temperature. This might imply that the rapidness of temperature drop is of great importance to the thermal comfort. Also, it came clear that the residents make adjustments in their way of clothing to match their general temperature level: with high temperatures, the residents tend to wear thinner clothes and walk barefooted inside the house, with lower indoor temperature they usually wear an extra sweater or suchlike. Therefore the ones with higher indoor temperatures may actually be more sensitive to draught from windows since especially the feet are sensitive to cold (Ronge, 1970). Other factors that seemed to be of importance for the thermal comfort experiences of the test was time of day and body activity level of the residents when the heat was shut off. More households have reported inconvenience to the temperature change in the mornings than in the afternoons. This could probably be explained by the fact that the residents undertook more sedentary work in the mornings (i.e. working at the computer) and that there were often some activities of cooking in the afternoon that raised the indoor temperature. Although quite a few of the controls of the heating were noticed, this was not expressed in the interviews as something particularly unpleasant (Sernhed, 2004).

Hot water availability

For the controls of the water heaters, only one control was noticed and only by one household. It was the 16-hour control that was noticed by the household that had the most household members (four persons). The water heater was shut off from 7 a.m. to 11 p.m. - at 4 p.m., the family was about to wash the dishes when they realized that there was only cold water in the tap. It is rather remarkable that no other household did the same discovery! This could possibly be explained by the fact that the size of the water heaters in these test houses are rather big (200 – 300 liters) and the number of residents is rather low (1-3 persons), which makes the dimensions of the water heaters quite ample of size. This condition is due to the move out of grown up children from these houses.

Customer attitudes towards load control

In the interviews the different limitations of load control and requirements from the customer point of view were discussed:

- Limitations: How and when may the utility control the customer heating system and water heaters?
- Need for information: Do the households now why the utility is interested in load management?
- Signal: Do the households want to be alerted before space heating and water heater is controlled?

- Compensation: Do the households experience a need for economical compensation if they agree to load management?

Most of the households think that there ought to be a limitation on the length of the control for heating for two, maximum three hours. The length of control should also be adjusted to the outdoor temperature, so that the control periods would be even shorter in cases of very cold weather. Only the household that experienced problem during the 16-hour control of water heater had opinions about limitations of the length of these controls, which it would like to limit to three hours at most.

Few households could imagine what are the utility incitements using load management. Some households thought that they themselves would save energy by letting the utility turn off the heating system and the water heater for shorter periods. In this way these households thought that they could save money. When realizing that load management isn't about saving energy but rather power, the issue of load management sometimes was questioned. It seems that there is a great need for information explaining the difference of energy savings and power savings, and what purposes the utility and other actors have to conduct these measures with household costumers.

In the interviews the respondents were told that the need for load management isn't necessarily existing on a daily basis but can arise rapidly so that the utility might not be able to tell the customers in advance. The question raised was then: Would the customers want to have some kind of signal (for example signal lamp) that shows when load management is on? Half of the households replied in the affirmative and the other half in the negative. Those who said yes presented different reason to this:

- To have the possibility to take measures to indoor temperature drop, for example light a fire or to put on a sweater.
- To be able to help the utility yet more by being more cautious about other domestic electricity use.
- That it would be honest of the utility to show when they are controlling.
- For the control of the water heater it would be good to have information in advance, so that the household members could plan for it.

For those who didn't want to know, there were also several reasons to this:

- If the utility adjusted the control periods somewhat to the household's routines, there would be no need for more information
- It is not necessary to know when as long as the control periods are short
- It is better not knowing since if one did, one would probably get irritated about it.
- If the controls would just occur on rare occasions, there would be no need to know.
- A couple of household with waterborne space heating system had already found a way to see if the heating or hot water was controlled on the boiler.

Nine of the ten households say that they would agree to "real" load management if it was carried out in the range of the experiment. The question of compensation was raised to the households. Here, seven of the ten households answered immediately that there should be some recompense, otherwise they would not be interested. The other three households had a more "collectivistic" opinion, meaning that if these measures could decrease the electricity price for all the customers, this would be good enough. The oldest households also talked about the importance of supporting the small local energy company in the competition with the industry giants (Sernhed, 2004).

Concluding discussion

Load management in the residential sector is not a new phenomenon neither in Sweden nor in other countries, however in Sweden many utilities were not interested in using load management after the deregulation of the Swedish electricity market in 1996. Conditionally, the deregulation has resulted in a decrease in reserve capacity, which means that the value of load management measures is even greater today.

The load management measures used in this study are using an existing remote meter system at the utility Skånska Energi AB, adding extra control cards and some installations to turn off and on the space heating system and the water heater in the ten pilot houses. In Sweden, there is a governmental promulgation for the utilities to read the customer electricity meters for at least four times a year. This promulgation is actually an incitement for the utilities to invest in new remote meter systems that facilitates more frequent readings and that may have features of load management possibilities like Skånska Energi AB has. This study shows that the function of this system works sufficiently for load management purposes and that there is a potential to decrease total load demand thanks to controlling heating and hot water systems in residential houses.

The behavioural part of this study proves that one can expect that there is a proclaimed willingness to entrust heating and hot water systems to the utility to control. Most of the households would probably demand some kind of compensation on the electricity bill. In case of agreement about load control, there is a need to consider resident's domestic hot water comfort and indoor climate. Households investigated in this study have stressed that the load controls should be limited in time and adjusted to outdoor climate conditions. Ideally, the load control activities should not be noticeable for the customers.

In order to summarize the results from the study it can be claimed that both load management and peak diesel plant are the solutions to solve the load problem for the utility, however, with completely different environmental effects. If choosing load management, the increase in CO_2 emissions, as well as other negative environmental effects can be avoided.

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V

What's on the top? Household load patterns and peak load problems

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Abstract

Most energy behaviour studies on households focus on the questions *how* and *why* we use energy and what can be done to lower energy consumption. Very few studies raise the question of *when* energy is used or examine the underlying explanations to load patterns. Due to economic and technical problems with electricity peak load, it is important to gain knowledge about how the load patterns of households contribute to power peaks, and to what extent households would accept a shifting of the load at certain critical periods.

This paper emphasizes these questions through a case study of ten households with electric space heating in southern Sweden. In these ten households, electricity use for heating, domestic hot water and appliances were measured as three partial loads with five minutes resolution. Energy diaries were kept by the household members. The combination of these two sets of data made it possible to see what appliances were used and what activities were carried out during peaks.

The highest power peaks in the households were based on electricity use for appliances, such as saunas, washing machines, dishwashers, and ovens. Coincidental use of large appliances, for example sauna and shower, gave the very highest peaks. Interviews indicated that there was acceptance among the households concerning a shift in the use of certain appliances at certain periods. However, all households did not have the same possibility to do this, due to their specific conditions and time restrictions.

Introduction

This paper emphasizes how every day life influences electricity load patterns in households. The examples given in this paper originate from a Swedish case study of ten households with electric space heating. The results of the study are to some extent country specific, but as there are many similarities in the way society and infrastructure are built in many countries (especially modern western countries), the discussion is interesting also in the broader perspective.

Households' time of use of electricity is something that is not very explored in behavioural energy studies. Background to the interest in this matter, in this study, is the question of demand response and peak load problems in the power system. In order to solve peak load problems some questions may be raised: What causes household peak load patterns and how can these patterns be altered?

Peak load problems and load management

Historically, peak problems have mainly been solved on the supply side, through increased electricity production, and oversized network capacity. This is called *supply side management*. Production and network capacity have to be dimensioned by the highest load peaks that occur in the system. In order to run the electricity system more efficiently, for instance by increasing the exploitation time, *demand response* can be used to influence maximum load demand and the electricity-usage patterns. Load management means enabling and motivating electricity users to decrease or shift load when needed. Load management is defined as a set of objectives designed to directly control or indirectly modify the patterns of electricity use of various customers of a utility. This is done to reduce peak demand, which in turn makes the power supply system run more efficiently [1].

Different peak load problems

Electricity must be produced at the same time as it is used. This necessitates flexibility in the electricity production and electricity networks. Problems with insufficient electricity production can arise either when there is a sudden (and sometimes unforeseen) demand that exceeds the production capacity or when there are operational problems with some power plant. The start-up of reserve power capacity is related to high costs. The reserve power often consists of gas turbines or oil condense power that have significantly higher variable production costs than hydropower or nuclear power. In Sweden, the costs are up to 10 to 15 times higher [2].

Another peak load problem refers to narrow sectors in the electricity grid, so-called bottlenecks, where the demand sometimes exceeds the transmission capacity. Bottlenecks can cause deficiency of electricity on one side and surplus on the other side. The bottlenecks are either temporary or structural. The temporary ones appear more seldom and can be the results of maintenance, technical problems or specific market conditions. Structural bottlenecks are a result of how the power system is built, and where the producers and users are located in the system [3]. Physically, a bottleneck can only be dealt with if electricity producers in a surplus area adjust their production to the actual demand, and producers in a deficiency area increase their production. Correspondingly, the users can lower their electricity demand in the area of electricity deficiency, and increase the demand in a surplus area [3]. The possibility to import electricity from other countries is limited by the maximum transmission capacity between countries.

Peak load problems are often discussed at a national level, although many actors have different incentives to solve peak load problems at the local or regional level. Peak load problems at the national level occur rather seldom, whereas economic problems occur much more often for the local actors, that is the electricity retail companies or the local electricity utilities (at least in the Swedish case). In Sweden, local utilities pay a load tariff to the regional network owner. When subscribed load level is exceeded, large penalties are charged, especially during weekdays when industries are fully running.

Load management

The benefits from using load management can be technical, economic, environmental and social. Table 1 shows a list by Abaravicius of different interests in using load management measures [4].

Table 1. Summary of interests in load management at customer and utility sides

	Customer	Utility		Producer	Grid operator	Society
		Retail company	Network company			
Technical	Avoiding fuse problems		Avoided network capacity problems	Maximum use of base (and cheapest) production units Avoided production capacity addition	Stable operation of power system on national level	Stable operation of power system on national level
Economic	Lower electricity costs Lower network costs due to lower fuse level	Lower risk when purchasing power on spot market	Lower demand subscription fees. Avoided investments in the network	Lower production costs	Stable operation on lowest costs Avoided/post-poned investments in the network	Economically sustainable electricity supply. Maximum reliance on local production
Environ-mental	Avoiding peak power plants nearby living area	Fulfilling goals established by environmental certification programs	Fulfilling goals established by environmental certification programs.	Avoided use of peak units (e.g. diesel or gas turbines) – which result in high emissions	Avoided new network construction	Least possible environmental effects
Social	Service compatible with the social activities					Power accessibility and equal conditions for all members of the society

Electricity use and load demand from a behavioural perspective

Although one may blame changes of weather conditions for many peak load problems, the use of electricity is caused by human actions and needs. Electricity is consumed because we use it to fulfil different functions. In the household, the energy helps us to create a warm and light indoor environment, to keep ourselves and the house tidy and clean, to satisfy our hunger and thirst, to get entertainment and information, and other practical functions that helps us in our daily lives [5]. "To use energy" is therefore never the main purpose when we buy electricity from the utility, but to use the functions that the electricity can serve. The product (or service) of electricity is not seen for what it is, but rather for what it can do.

In developed countries the use of energy is incorporated into almost every activity that people involve in. We turn on a light to be able to read a book. If we are hungry and take something to eat, we use energy for storing the food, for cooking the food and for washing the dishes afterwards. To keep instant track of how much energy we use is an almost impossible task, since most of our routines are carried out without much reflection. Even if we would reflect upon all our daily activities, the volume (and price) of the used energy would still be hard to control. Without installing specific meters and displays on our appliances, we do not see how much energy we use until afterwards, when the energy bill comes. And at that point, too long time has passed between the activities and the feedback, which makes it hard to recall our act in detail.

Certain energy-using functions are more obvious and observable to the user than others. These functions either require the user's attention or are more visible than other functions. In one study where people were asked what they could do to save energy in their home, the most frequent answer was that they turn off the lights when leaving a room. Although turning off the lights is one good example of what one can do to save energy, the energy saved from turning off the lights is much less than, for example, lowering the indoor temperature with one degree Celsius, something which was a rather rare answer in the study. [6]. One explanation of the energy- saving alternative given by the respondents could be that turning off the lights is a visible action that is therefore an action easier to have in mind than lowering the indoor temperature when none is at home.

Everyday life in a context

Daily peaks in the electricity system arise from institutional influence on our use of time. Schools and working places often have similar time schedules. This means that many people have to get ready for school or work at almost the same time and perform certain activities, such as taking a morning shower, making coffee and toast for breakfast or other, often culturally conditioned behaviour, at the same time.

In the field of human geography, our daily life is discussed from the concepts of restrictions, projects and activities [7]. People adjust their daily lives to different restrictions that affect the freedom of action. There are different kinds of restrictions:

1. **Restrictions from authorities and means of control.** These restrictions are created by organisations whose legitimacy and authority are prescribed by laws and regulations. Examples of this can be schooling, timetables for transport, access to childcare system and work hours.

2. **Restrictions through interaction between members in the household or immediate family.** The restrictions are built on promises and obligations that are maintained and constantly reconsidered in the daily life.

3. **Restrictions due to deficient capacity**, for example tangible assets, knowledge, physical, economic and technical resources.

Physical restrictions of our bodies greatly influence our daily lives and when we use electricity in our homes. When we sleep for example, we do not carry out electricity using activities that need our direct attention. Indirect electricity use, where a system runs the equipment or the appliances can, on the other hand, be used any time.

Flows of *activities* occur in our daily lives either by choice or by the influence of different restrictions. Certain activities are carried out almost without any consideration. Many activities are included in different *projects* and others can be included in several projects at the same time. For example, the activity of “riding the bike to work” can be part of the project of “transporting yourself to work”, the project “to maintain a healthy body” and/or the project of “saving the environment.”

One common way to categorise the electricity use in households is to divide it into electricity use for space heating, for hot water preparation and for lighting / appliances. I will use this categorisation to pinpoint how these functions differ in regards to our behaviour.

Heating

The need for heating is influenced by different factors:

- External factors: Climate zone, weather and temperature
- Physical factors of the house: House size, construction and insulation
- Internal factors of the individuals living in the house: Comfort needs and preferences, which in turn are influenced by for example health, body activity level and convenience

Heating is one example of a function that often is automated and run by a technical system, especially electrically heated systems. The more automated the function is, the less involvement is needed from the user. As long as everything runs smoothly, the user does not have to do anything. To be able to control the function, the user has to have knowledge about the system and access to the controls. Lacking this knowledge or access, the user has no ability to control the system and this can be a real problem if one wants to achieve energy savings or a better indoor comfort. Without device that shows momentary load demand for heating, it is not easy to know how much load is on at a certain time. The heating system might be put on an adjusted temperature level, for example at 21°C, and if the system runs smoothly it will regulate the radiators automatically without any interference of any human action.

Thermal comfort for an individual is defined, according to ISO 7730, as “that condition of mind which expresses satisfaction with the thermal environment” [8]. The experience of the thermal comfort is personal and there is no perfect level that suits all. In households with more than one person, the indoor climate can be a reason for conflicts and compromises. Some studies show that women are more sensitive to low indoor temperature level. Energy-efficient behaviour such as lowering the temperature level then strikes harder on women than on men [9].

Heating is a great source to the energy consumption in Swedish households. In one study from 1991, the energy for space heating together with energy used for ventilation stood for 60 % of the total energy use in a house and the domestic hot water for 9 %. The houses in the study were all built after 1965 and the households consisted of families with children in different ages [10]. But much has happened with energy efficiency for heating in detached houses the last decades. A recent study shows that energy use for heating nearly goes halves in a new detached house in Sweden compared with older houses. In the most energy efficient houses on the market the energy demand for heating can be down to 80 % lower [11]. Hence, the energy use as well as the load demand for heating can differ very much between old and new houses. The load demand for heating varies with the conditions of climate, wind and time of the year, which means that the load demand increases in the heating season. In countries with warmer climate than Sweden, this can be compared with the need for cooling.

Domestic hot water

The use of hot water refers to routines of cleanliness like taking a bath, taking a shower or washing our hands. Or it can refer to activities like washing the dishes, either by hand or with a dishwasher that uses preheated water, or doing the laundry with a washing machine that uses preheated water. When using domestic appliances, the water use is hidden for the user.

One could say that the use of hot water is a more direct form of energy use than space heating since it often is related to human activities. The user can get some indication of the energy usage by looking at the volume of water streaming from the tap. But even if we can see the volume of the hot water used, there is still no information of how much electricity the water heater needs to prepare the hot water.

Domestic electricity use

The domestic electricity use has continuously increased in the last decades. The slope has flattened the last decade, but there is still an up going trend. In 1970, a Swedish household in a detached house used about 4000 kWh per year for domestic electricity use. Today the electricity use is close to 6000 kWh per year [12].

The electricity use per capita is systematically higher in multifamily houses, than in detached houses. This is due to the minimal level of standard of a normal home, which means that some electrical equipment and electricity use will be the same whether the household contains one member or more. Since the households systematically are bigger in detached houses than in apartments in multi-family houses, the domestic electricity use is yet higher in detached houses. There is a trend towards a greater share of households with only one household member. Number of dwellings in the country is a key factor for further development of domestic electricity use, but we cannot know if the trend will continue. There is a limit of how small a household can be and the present tendencies, for example immigration, birth rate and living expenses, can change the circumstances [13].

Our holding of electric appliances has dramatically increased in the last decades. This is one reason why domestic electricity use has increased steadily during the years. Technical development of energy efficiency for many large appliances has however counteracted the increase of energy use. Refrigerators and freezers, as well as washing machines and tumble dryers are today much more energy efficient than ten, twenty or thirty years ago. The answer to the increase of domestic electricity use may then to a certain extent be explained by the introduction of new electricity appliances in our homes, such as computers, printers, TV, VCR, CD-players and battery chargers. Many of these appliances use stand-by power for preserving the setting of clocks and programs.

For some appliances, the energy use is highly affected by the usage patterns in the household, whereas others run autonomously. Lighting is one example where the users greatly influence when a lamp is in or off, whereas the use of freezers and refrigerators are more influenced by a thermostat (although habits like how often one open the door or how often one defrost also influence the energy use to some extent). The share of electricity use for different appliances or activities was investigated by the Swedish Energy Agency in one study from 1998 [14], see Figure 1.

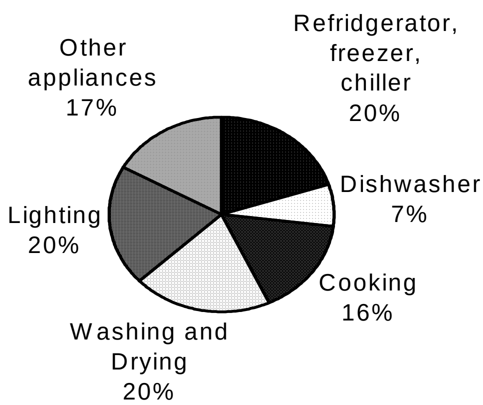

Figure 1: Share of electricity demand for different appliances in Swedish households.

Study of household electricity use and load patterns

To be able to study how people use electricity in a time perspective, that is, to look at their "peak behaviour", a case study was carried out with ten households in southern Sweden. The purpose of the study was to investigate what activities and what appliances in the household that contribute mostly to high peak load. A combination of methods; frequent electricity metering and energy diaries were used in this study. Follow-up meetings were carried out with the households after the diary period were the two kinds of data were discussed.

Selection of households

The ten households that were selected for this study, were all the customers of Skånska Energi AB, a Swedish utility located in a town called Södra Sandby in the south of Sweden. The selection of the households was not just made for this particular study, but also for load management experiments. Hence the selection was more focused on technical criteria of, for example, their heating systems, than on demographical factors, such as household composition and age. Household composition and heating system are stated below:

K1 (House 1): Composition: Married couple in their 50's with a grown up son, still living at home. Both are working. Heating system: Electric boiler, wood stove and water heater of 200 litres.

K2: Composition: Married couple in their 60's, the wife works and the husband is a pensioner. Heating system: Electric boiler with integrated water heater of 120 litres. Air to air heat pump.

K3: Composition: Widower, pensioner in his 70's. Heating system: Electric boiler and water heater of 200 litres.

K4: Composition: Married couple, pensioners in their 80's. Heating system: Electric boiler with integrated water heater of 120 litres.

K5: Composition: Married couple in their 50's, both working. Heating system: Electric resistive with oil filled radiators, fire place and water heater of 300 litres.

K6: Composition: Married couple in their 60's, both working. Heating system: Electric resistive, mostly with oil filled radiator and floor heating 8m2 and water heater of 300 litres.

K7: Composition: Married couple about 55 years, both working, one grown up son still living at home. Heating system: Electric resistive and water heater of 300 litres.

K8: Married couple about 55 years, both working but the husband was on the sick-list during the study. One grown up son still living at home. Heating system: Electric resistive and water heater of 300 litres.

K9: Younger cohabit couple in their 30's, with a baby. The man worked and the woman was on maternal leave. Heating system: Electric resistive and water heater 200 litres.

K10: Cohabit couple in their 40's. The man was working and the woman was unemployed. Two teenage kids were living in the house every fortnight. Heating system: Electric resistive with oil filled radiators and water heater of 200 litres.

The houses were all electrically heated, but some had water borne systems and some have electric resistive radiators. Seven of the houses were detached and three (K6, K7 and K8) were semidetached. K5 was the biggest house (150 m2 and basement 150 m2). K1, K2, K3 and K4 were somewhat smaller (145 –186 m2) and the smallest were K6, K7, K8, K9 and K10 (between 95 and 118 m2). The number of household members varied from 1 to four persons.

Metering

Two extra electricity meters were installed in each household which made it possible to measure electricity load for space heating, hot water preparation and total load separately. The domestic electricity load was then calculated as the difference between the total load and the load for heating and hot water. During the diary period the three partial loads were measured with five minutes resolution.

Energy diaries

Diaries have been used in other types of studies to decide where and when events and processes occur. The interplay between time and space has been the focus in time budget surveys where activities and the use of time in populations have been investigated. To be able to investigate habits and usage patterns in our every day lives, a real time perspective must be taken on [7]. Figure 2 shows the differences between a real-time perspective and an added time perspective. In an added time perspective, the information about how many times a specific activity is carried out disappears and so does the context in which the activities are carried out.

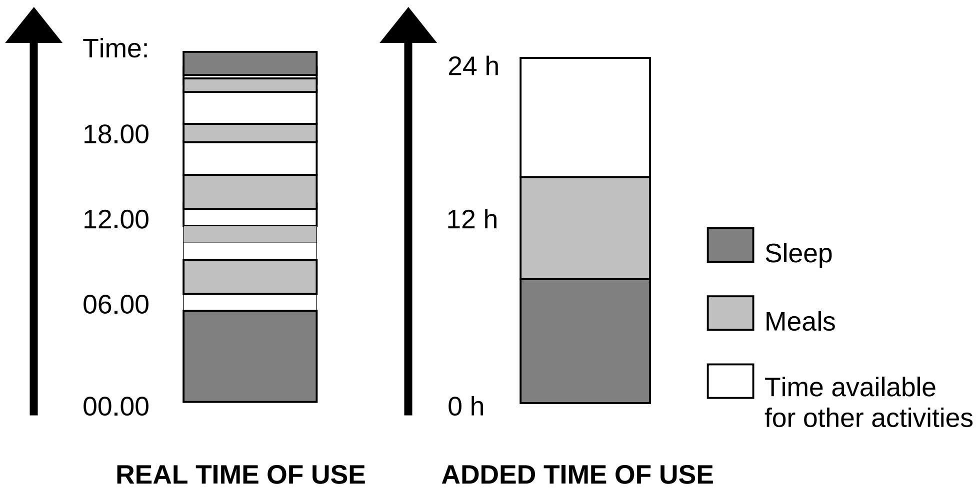

Figure 2: Different time perspectives

Let us assume that we have an added energy use instead of an added time use. The added energy use then corresponds to, for example, the yearly energy usage in a household. The yearly energy use does not say anything about *when* the energy has been used or for what, nor if the energy has been used evenly over the year. For this purpose energy diaries together with frequent electricity metering have been used in this study.

All members in the ten households noted every energy related activity they performed in their personal energy diaries (except for the baby in K9) for four days in January 2004. The households themselves chose diary period. They had to choose four successive days in January, including one weekend. The diaries were made of prepared diary sheets. Each sheet consisted of a table with five categories; Time, Activity 1 (What I am doing), Activity 2 (If I am doing something else at the same time), Energy appliances used and Comments. One or two days after the diary period, household and researcher met and discussed the outcome of the energy diaries and compared the notes to the load curves for total, heating, hot water and domestic electricity use. Activities and appliances could then be linked to the load pattern in the diagrams. Some electricity load that did not have any corresponding notes of energy use in the diaries was found. For instance, the electricity use from floor heating was detected on the load curves in one household.

The households were also interviewed about their possibilities and acceptance of shifting the use of certain appliances and electricity use at certain periods, if they would have to pay for load demand on the electricity bill in the future.

Results

Combining the methods of frequent metering for three partial loads with notes from the energy diaries has made it possible to do different analyses of energy and load behaviour in the households. More results from this study are reported in a separate report [15].

Heating

As heating is an autonomous function in the ten households, there were not very many notes on this in the diaries. Lighting a fire and lowering the heating during the night were two examples of behaviours that were noted that referred to heating. Lighting a fire in the stove or fireplace, however, did not show on the load curves. This might be explained by the fact that the households who noted this activity had outdoor sensors so that differences in indoor temperature were not compensated for. Household K1 and K4 lowered the temperature on the electric boiler before going to bed, and then raised the temperature again in the morning. This behaviour resulted in an energy saving of approximately 9 kWh for K1 (1kW*9 hours) and 7 kWh (0,84*8 hours) for K4 per day during the diary period. Although this behaviour results in significant energy savings, it can also give rise to a recovery load. For K4 this was not evident, but for K1 it gave rise to a recovery load of 2,6 kW witch was approximately 1 kW higher than the stabilized load level.

Different heating systems behave quite differently. In Figure 3 the heat load curves from three households are put in the same diagram.

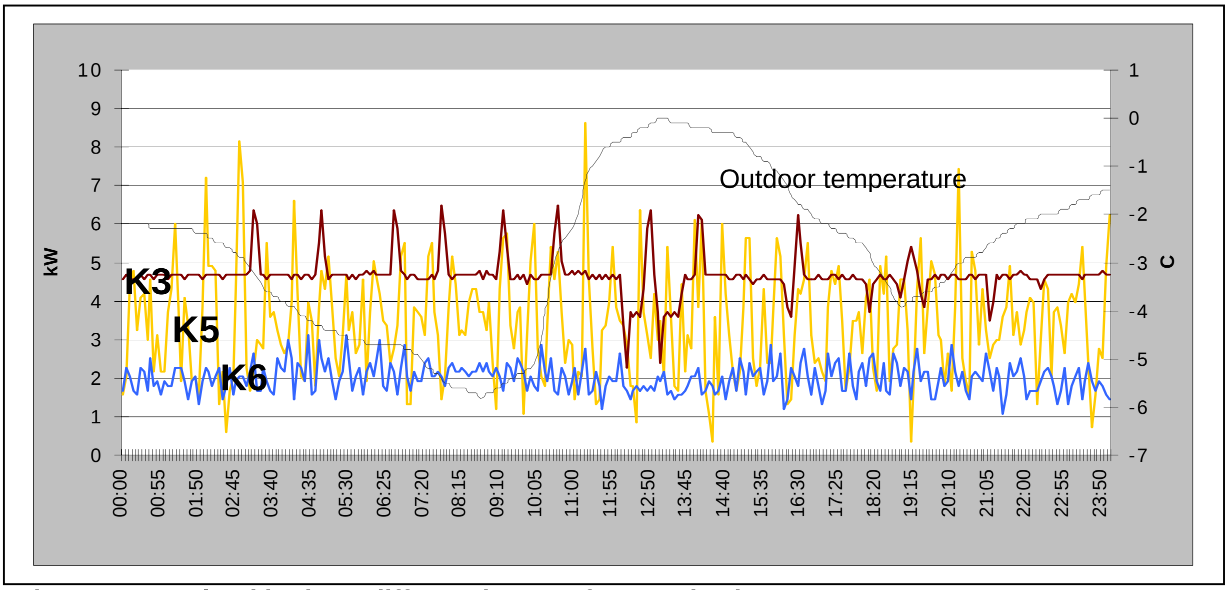

Figure 3: Heat load in three different houses for one day in January 2004.

Principally two factors seamed to conduce to the differences in the shapes of the load curves, namely the size of the houses - or more specifically: the heated area in the houses, and the kind of heating system and automatic control. The prerequisites for the houses were as follows:

- House K3, which had the highest load for heating in general of all the houses, had a living space of 180 m^2. The heating system was an electric boiler with an outdoor sensor, and the internal system was waterborne.
- House K5 was a house of 300 m^2 (150 m^2 was heated basement). The heating system was electric resistive heating with thermostats on the radiators.
- House K6 was a semidetached house of 118 m^2. The heating system was electric resistive heating with oil filled radiators and "soft heating" system with outdoor sensor.

House K3 had an electric boiler and the heating demand for this day seamed to be in accordance to one of the boilers stage of load level considering the even load shape. Shorter periods where yet another load step is activated are clearly showed in the diagram. The houses K5 and K6 had electric radiators and the load patterns from this equipment oscillated much more. House K6 had, in contrast to K5, a "soft heating" system and, moreover, a large share of oil filled radiators. The fluctuations between the peaks and the valleys of the load curve were apparently lower for K6 than for K5. This was probably due to the soft heating system.

Hot water use

Taking a hot bath, a shower or washing the dishes were the three activities that gave rise to a large use of electricity for hot water preparation in the ten households. Other types of hot water use that were reported in the diaries, for example getting hands washed, shaving or washing the floor, did show on the load curves, but did not give rise to any larger electricity use.

Both load level and electricity use were influenced by:

- The equipment: The dimension and the load level of the water heater, the adjustment of the thermostat and the insulation of the water heater matters
- The user activities and the habits related to the different activities (for how long one takes shower, how much water one use when filling the bathtub or washing the dishes etc)

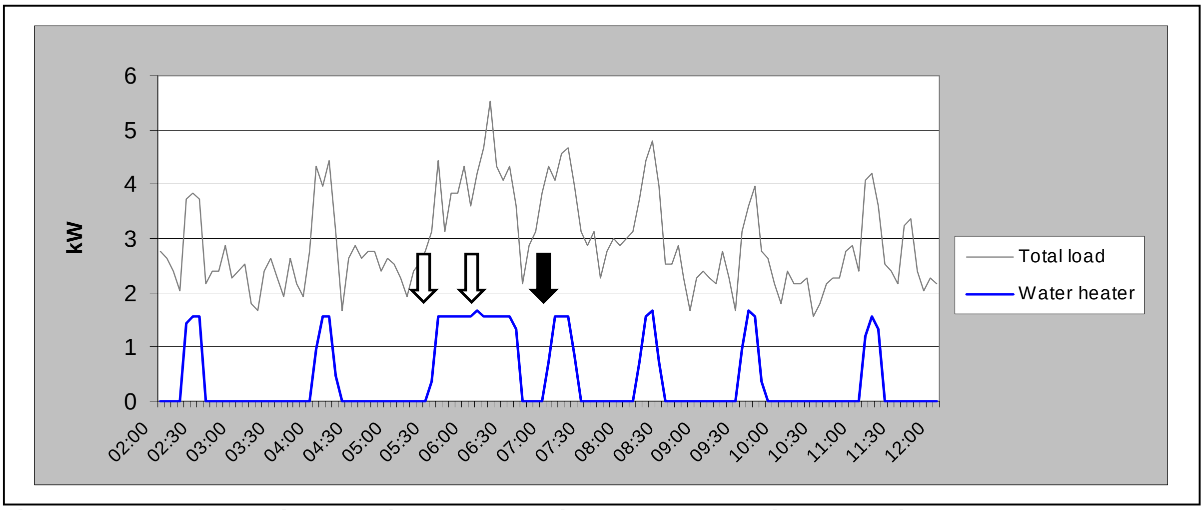

Figure 4: Use of electric water heater, Saturday 16 Jan, 2004 (House K6).

Figure 4 shows electricity use for hot water preparation in one household (house K6) in one weekday morning. Only three peaks in the diagram were due to hot water tapping. At about 05:20 the man took a shower and at 05:42 the woman did the same, which gave rise to an electricity peak that lasted in one hour and twenty minutes. At 06:56 the couple washed the dishes from breakfast. As one can see, the peaks reached the same load level every time – about 1600 W. The other peaks shown in Figure 4 referred to heat losses and came from reheating the water heater.

The sizes of the water heaters in the households varied from 200 – 300 litres with a maximum load level of 3 kW. In K6, K7 and K8 there were two load steps on the water heaters. In the study it was showed that the size of the water tank could influence the habits of hot water use. For example, the households were aware that they could run out of hot water if several persons were taking showers in a turn. In some households this did lead to an order of priority, where the ones who shower the longest had to wait until last of all. Another strategy in some other households was to regulate the time of use so that some members took their showers in the morning and some in the evening.

Domestic electricity use

Domestic electricity is used for an abundance of different functions in our homes: lighting, motor power, pump power and heating of all sorts of equipments. The electric power helps us to heat oven and hobs so that we can cook, to heat the iron so that we can get rid of creases in textiles, to heat water to wash clothes in the washing machine or to wash the dishes in the dishwasher.

In the diaries the household members have noted what electric appliances have been used during the diary period. All ten households used TV set, kitchen range, lights and shower during the period. Washing machine, coffee maker, vacuum cleaner, oven, microwave oven, hair dryer and computer were also examples of appliances frequently used in the households. All the households had got freezers and refrigerators, but few noted this kind of appliances since these are not so much linked to daily activities. As a matter of curiosity, some of the more uncommon appliances noted by the households could be named: air humidifier, electric coffee mill, electric squeezer, fryer and amateur radio station.

A large part of the domestic electricity is influenced by personal activities. But there are also a “base load” that primarily consists of the use of electricity from freezers, refrigerators and stand-by power. The electricity load from this base load varied from 250 W to 1250 W in the households. This means an electricity use of about 6 to 30 kWh per day (which means from about 2190 kWh to 10950 kWh per year). Behaviours like overhauling the stand-by power usage in the house or replacement of old freezers or refrigerators can really save a lot of electricity and money and decrease the total power load in the household!

Analysis of highest peak load from domestic electricity use

One analysis was made about what activities and appliances it were that contributed to the highest power peaks in the households (during the diary period). Each household’s ten highest peaks from domestic electricity use measured by five minutes were compared with the notes from the diaries. Following appliances or activities gave the highest load: Saunas (5-6 kW), washing machines (2-3,6 kW), ovens, car heaters and engine heaters (fully 3 kW), electric fires (1,5-2 kW).

Two households have got saunas installed in their houses and have been taking a sauna during the diary period. Heating the sauna gave rise to the highest load peaks of all, about 5 – 6 kW. Considering the fact that saunas can be on for several hours, plus the fact that taking a sauna mostly is combined with taking a shower (1,6 - 3 kW for the households in the study), electricity customers should be made aware of the load pattern from saunas if they are going to be charged for load demand in the future.

Washing machines gave rise to some of the highest peak loads in eight of the ten households. Washing machines were frequently used in the households and some households used them almost every day during the diary period. A normal washing programme takes between 45 and 80 minutes, and the load demand is typically higher in the beginning of the programme when the water is heated. Drying cupboards and tumble dryers gave rise to almost as high peaks as washing machines. These appliances are often used successively or at the same time, which together give yet higher load.

The usage of ovens resulted in high peak load for seven of the households. Combined with other cooking activities high coincidence loads were reached.

Electric heaters, such as car heaters, engine heaters and floor heaters had a relatively high load demand. Since the function of these appliances often is autonomous, especially when using a timer or thermostat, there is a risk that the households don’t pay attention to the electricity use from this kind of equipment.

Composition of the highest electricity peaks

Looking at the very highest electricity peak (from the four-day diary period) in each of the ten households, an attempt has been done to divide the peak into electricity use from different appliances. Since there were data about the three separate loads (total, hot water and heating) but not for each appliance, the load curves have been compared with diary notes and the electricity use from noted appliances have been approximated. The analysis is not exact, but it gives some idea of the appliances relative contributions to household peak load. See Figure 5.

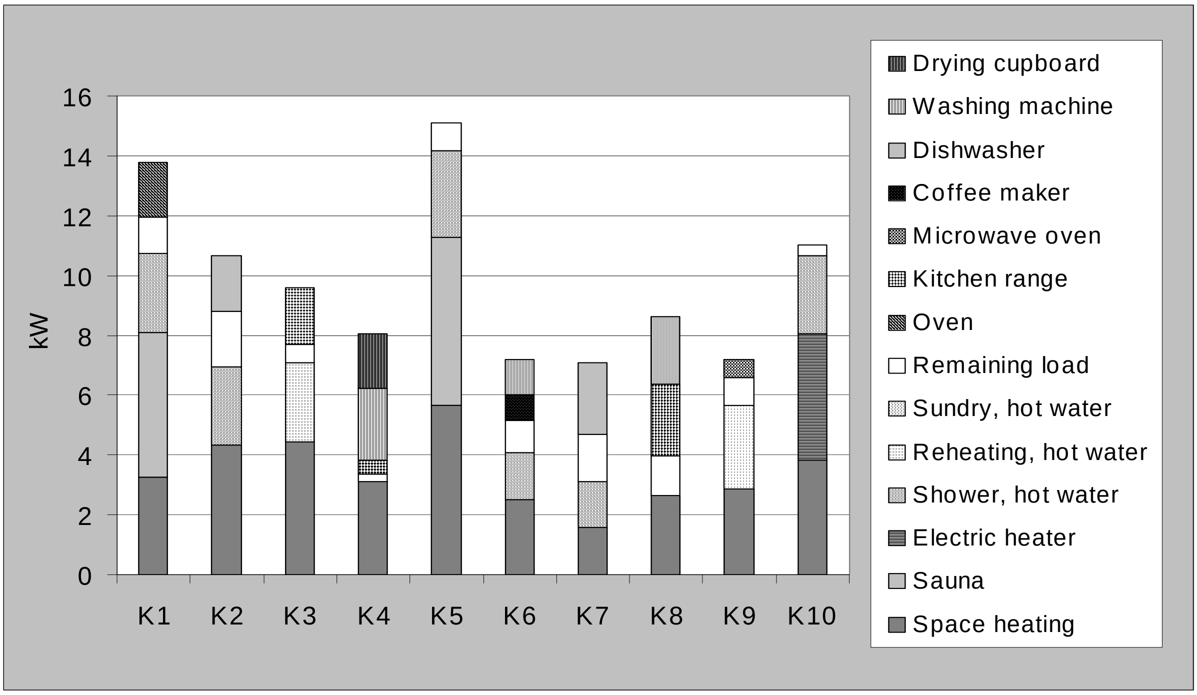

Figure 5: Composition of 10 household’s highest peak load

The heating load could be seen as a base load in wintertime for all of the households. The load for heating in this diagram didn’t reach the highest electricity peaks for heating in the study, but nevertheless it stands for one fourth to one third of the total peak. In eight of the households some part of the peak relates to electricity use from the water heater. In six of the cases the shower has been used. A large part of the peaks consists of load from domestic electricity use. In K1 and K5, the sauna was used and in the other households activities such as cooking, taking care of the laundry or using the dishwasher were carried out. The field in the staples named “remaining load” was based on electricity use from refrigerators, freezers, lights and stand-by power.

The households were interviewed about what changes of electricity use they thought they would adapt to, if the electricity utility made them pay for load demand (either by a time-of-use tariff or a tariff with a load component). Activities such as washing and drying linen and turning on the dishwasher were the ones that all of the households came up with immediately. This kind of activities is basically run by machines and doesn’t require so much attention. The supplementary work when the machines have stopped still has to be done though, and this work would be postponed. The two households with saunas installed in their homes, said that they were flexible when to use the sauna. If the low tariff periods were not too late in the evening (or too early in the morning) they could wait until the electricity price was lower.

Cooking was one activity that the households did not want to shift in time. They wanted to be able to cook whenever they were hungry or felt for it. The use of hot water could eventually be adjusted to times with the lower tariff. Just a few of the households talked about technical solutions like, for instance, installing an accumulation tank for hot water storage which makes it possible to turn off the water heater in high tariff periods.

This analysis was made from the data of the households’ highest peak during the diary period, which means that only the appliances that were used during this specific electricity peak is shown in the diagram. Other activities such as ironing, vacuum cleaning or hair drying (all about 1 kW) would also have showed in the diagram if these activities had been performed during the period.

Now, let us make an intellectual experiment. Let us remove the load from the activities that the households say they are willing to move from the diagram in Figure 5. What are the potential load savings? If we remove the load that comes from drying cupboards, washing machines, dishwashers and saunas; the load from the electric heaters in K10, since this load easily could be moved to low tariff times, and the hot water use that coincides with taking a sauna, the households would reach load savings between 0 and 57 % (mean value: 31 %) There would be no savings in K3 or K9, moderate savings of K2, K6, K7 and K8 and large savings in K1, K4, K5 and K10.

A story of one afternoon...

A mother and two kids come home to the family house. They have just left work, school and the day-care centre for the day. It’s November and already dark and cold outside. They long to come in to the heat and the light inside. The kids are wining of tiredness. They are hungry and tired after a long day. Now the dinner must be served quickly before the youngest kid falls asleep in front of the TV set. The older kid has had his fun jumping in puddles during the break in school. His coat is all muddy, and he himself has mud in his hair. The coat has to go in the washing machine and the kid in the bathtub. Dinner is not prepared. The minced meat is in the freezer and must be thawed in the microwave oven. Pasta Bolognese is on today’s dinner menu. Yesterday’s dirty dishes from dinner and breakfast are piled on the kitchen sink. There are no clean glasses left, so the dishwasher has run one batch. The dishes are rinsed with hot water – there are stains of ketchup and egg and they won’t disappear unless they are rinsed first – then the dishwasher is switched on. The electric kettle is turned on for the spaghetti water, and at the same time the older kid is shouting for help to get up from the bathtub. This kid has still shampoo in his hair and his mother takes the shower and helps him rinse his hair. When the kid is ready, cooking is continued in the kitchen. The minced meat is now thawed up and the water in the electric kettle has boiled and is poured into a big pot. Two hobs are switched on, one for the spaghetti water and one for the mincemeat sauce. The electric kettle gets filled once more; the spaghetti needs more water to boil in. Onion, garlic and celeriac are peeled and one tin of tomato paste is opened with the electric tin opener. The clock is striking six and the kids runs up and turn on the children’s programme...

Let us end the story of this family a cold November afternoon. During one hour, the family manage to turn on several electric appliances: washing machine, dishwasher, two hobs, electric kettle (twice), electric tin opener, TV set and hot water for rinsing the dishes and bathing. For the total energy use in the house this period, add the use of energy for heating, lighting, refrigerator, freezer and stand-by power from different appliances.

If one would ask the mother in the story if she thinks that the energy used during this hour in the afternoon is unnecessary, the answer would most likely be *no*. All the activities have been essential to fulfil different needs in the household: to be warm, to get food, to keep the persons, the house and the clothes clean for next day. Is there any load that could be shifted to other times? Well, maybe. The kids are hungry and tired and the cooking has to be quick. With better planning, the minced meat could have been thawed over night in the refrigerator. Then, the use of the microwave oven could have been avoided. Cold food could have been served, but maybe there is a decision to serve hot meals in the evening in order to make sure the kids eat at least one cooked meal every day. This could be part of the project “family spirit” or “healthy bodies”. The wash up of the coat could maybe be postponed. But the coat is going to be used the next day and it has to get dried. The washing of the dishes maybe could have waited, but there were no clean glasses and some were needed for the dinner. Besides, no one in the family manage to put the dishes in place if it gets too late.

The family experience time as a deficient capacity (or resource). Different restrictions in the society are influencing the family’s freedom of actions; school hours, work schedules, timetables etc., are shaping the family members lives. When the family gets home, there are obligations: to do the dishes, prepare the food, take care of the laundry and the homework – things that have to be done here and now. Physiological factors like hunger or need for sleep make themselves reminded. The stomach is rumbling at five. The kids are tired and hungry and the experience shows that cooking has to be quick, or else the kids fall asleep without eating. After the kids are put to bed, the parents might be too tired to do any more housework.

Concluding discussion

The deregulated electricity market in Sweden, as well as in other countries, has increased the interest in demand response, which means that the electricity users should share the costs of peak load, and they should adapt to new behaviours that considers peak load problems.

Some problems come up when talking about demand response. One problem is that our use of electricity or energy often is hidden for us. This is because we do not know how much energy different appliances and equipment need. We simply do not think in terms of energy use, but rather in terms of activities. When carrying out different activities we use appliances and equipment and they in turn use energy. Thus, the construct of energy use is quite abstract for people. Then, if the construct of energy use is abstract, what about the construct of load, that is, energy use per time unit?

Some results in this study were showing how heating systems, water heaters and big appliances in the households contributed to the load pattern. These patterns were not easy to predict. In households with many members, the load patterns get even more complicated.

Using load management measures that means that the customer itself has to keep track of its peak load behaviour, might not be very fair to the customer (the use of a tariff with a load component for instance). The customer needs help to either monitor the momentary load, or to limit the power use so that it does not exceed a certain level. This could be done with a load guard. The result of the intellectual experiment in the study showed that there could be some potential in time-of-use tariffs to influence customers to adapt to new load saving behaviours. Here, the customers need help to learn what activities and equipment it is that contributes to high power peaks and large electricity consumption, and if there are any technical solutions that could be installed to help shift load.

All households don't have the same possibilities to shift their energy use in time. The mother in the story told above, felt that time was a deficient capacity. If time is restricted, there is not so much freedom of action. Therefore, a time-of-use tariff would strike harder in some households.

The discussion of how people think of their everyday life in terms of activities (where many of the activities happens to require energy) is vital in this paper. The energy is needed to fulfil different functions or services in the household. So, should the energy companies really be selling energy, when the customers requires services like a nice indoor climate, a good hot water comfort and so on? This idea of servicization is not totally new, but the energy companies do not use it to any greater extent. This idea, however, could have many advantages. If an energy company would take over the heating service in a detached house for example, the customer would pay for heat with a certain comfort level, but not for the energy use. Thus, the company could optimise the system from whatever factors it liked; energy use, energy costs, system sustainability, environmental concern or to remedy peak load problems. There are, of course, some objections to the idea. For instance, there might be some legal questions of ownership. Who owns the equipment and what happens if the house is sold? Or there might be some trouble with integrity if the company has to have access to the heating system.

Looking at the composition of the highest peaks in the households, it became evident that domestic electricity use contributed to a large part of the peaks. Big appliances, such as washing machines, dishwashers, tumble dryers and the like has been improved of their energy performance over the years. Maybe, manufacturers of white goods in the future also will have to consider peak load performance when developing new appliances.

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VI

More or Less about Data

- Analyzing Load Demand in Residential Houses

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ABSTRACT

Load demand in residential houses is a significant contributor to peak load problems experienced by utilities. The knowledge about demand variation in households is fairly limited as well as the use of various tools to analyze the demand. Many utilities have recently installed interval (hourly) metering at their residential customers. The availability of hourly data is a significant progress, however, the utilities use this data only to a limited extent, mostly for billing purposes only. This study aims to discuss the possibilities and the benefits of using this valuable data.

There are several established load analysis tools, such as load curve, typical load curve, load duration curve, load factor, superposition factor, etc., which utilities could apply and develop to provide feedback to small electricity users. Among other benefits, the hourly load data analysis can provide the detailed characteristics of load demand, define the consumption patterns and can help to identify which households contribute most to the utility peaks. This information is essential when developing new energy services, appropriate pricing, load management strategies and demand response programs.

Through the analysis of strengths and weaknesses of different load analysis tools, this paper defines the knowledge they could give, how applicable they are and what value they could have both for the utility and the residential customer. The study is exemplified with ten cases of households with electric space heating in Southern Sweden.

Load demand and load data in households

Traditionally, when approaching load demand problems, the focus is on bigger electricity users (industrial). But the fact is that the residential, commercial and services sector accounts for half of the total electricity consumption in Sweden (Swedish Energy Agency 2003). Electric space heating currently accounts for just over 30% of the total electricity consumption in the sector. High electric load demand variations occur in winter season together with temperature variation. Load demand in Sweden increases by 350 to 400 MW for each ºC of outdoor temperature drop (Pyrko, 2004). Furthermore, load demand in the residential sector varies significantly during the day and normally has its peaks during morning and evening hours.

The dominating energy source for heating and domestic hot water for detached residential houses in Sweden is electricity. An increased number and a variety of household equipment may also lead to load shortages if used simultaneously.

Most energy experts agree that the residential sector should be seriously considered when approaching peak demand problems and ensuring a well functioning electricity market.

The existing knowledge about demand variation in households is fairly limited. Many utilities have recently installed or consider installing interval (hourly) metering at their residential customers. This is partially enforced by the new law of billing on actual electricity use

(Sernhed 2004). The availability of hourly electricity use data is a big step forward, however, the use of various tools to analyze the demand is limited. The utilities use collected data mostly for billing purposes.

The Swedish electricity market was de-regulated in 1996. However, if private customers wanted to change their supplier (retail company) they were forced to invest in a new electricity meter with hourly metering. The cost of such a device was typically around 900EUR. Very few customers changed their supplier at this stage (Matsson 2001). The requirement for hourly metering was abolished in 1999. It was replaced by a profile-settlement, meaning that different consumption patterns are applied when estimating the electricity consumption within a specific period of time. Each pattern is valid for all customers within a specific geographical area (Wallin 2005).

The major advantage of new profile-settlement was that the electricity consumers with smaller consumption (residential) were able to switch electricity supplier and directly benefit from the new electricity prices without having to invest in the metering system. One major disadvantage was that the connection between real physical electricity use and customer electricity cost in high-peak periods vanished (Wallin 2005).

There are a number of suppliers of new metering systems promoting their products. With the latest technical development of automated meter reading (AMR) systems the residential customer becomes more “visible”. Hourly data is available now both to the customer and the utility. New meters allow even more detailed statistics as well as opens new possibilities for customer-supplier dialogue and the development of new energy services. This is a new possibility but at the same time a new challenge, requiring reconsideration of long term customer – utility relations. In the present market conditions keeping the customer becomes the major task for a utility. The use of modern metering and communication system could be seen as a competitive advantage influencing customer choice.

The objective of this paper is to discuss the ways and benefits of using this valuable end-use data. The electricity use of ten pilot households is shown as an example of using the analysis tools described in this paper.

Analyzing load demand

Several characteristics can be derived when analyzing load on the demand side to describe load demand conditions as:

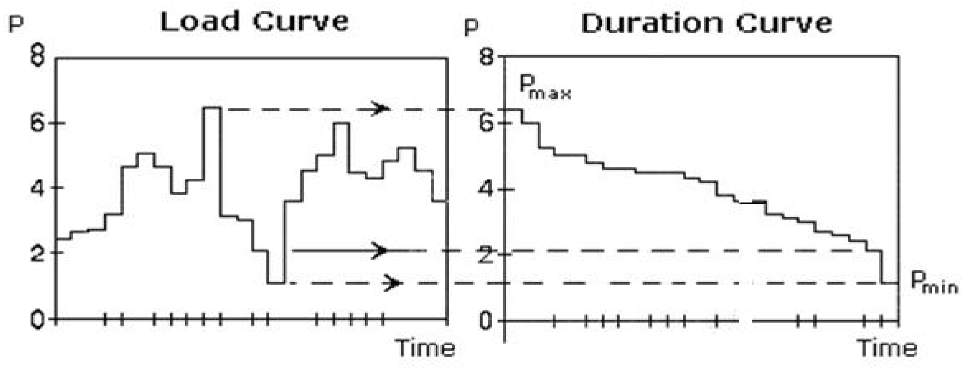
- Magnitude of energy use and load demand
- Variation of the demand in time
- Minimum and maximum demand values
- Duration of minimum and maximum load
- Contribution to total pattern/total utility load

There are several established load analysis tools, such as load curve, typical load curve, load duration curve, load factor, superposition factor, etc, which are used to describe these conditions. The definitions, interpretation and applicability of these tools are discussed in this section.

Load curve and load duration curve

Load curve illustrates variation of load demand during a specific period. A load curve can be converted into a *load duration curve* showing duration of a particular load demand. A graphical explanation of load curve and load duration curve is given in Figure 1.

Figure 1. Load curve and load duration curve (Pyrko 2004)



Source: Pyrko 2004

The load curve is a good visual representation of electricity use in a household and its variation over time. It shows minimum and maximum use values against time-of-day and, depending on the given resolution, their duration. It could be considered as a "user friendly" way to explain the customer peak load phenomenon and can be an incentive for the customer to look at what is beyond the needle peaks in the consumption. Therefore this method should be an attractive one for the customer (expected to have some sort of behavioral influence) and convenient for the utility. However, to be realistic, one should keep in mind the question when and why would customer care to look at their load demand. Three conditions could be emphasized:

- Customer is interested to see the existing pattern
- Customer is interested to see the changes when some measures (energy/load saving etc.) have been implemented in the household
- Customer has a direct incentive to care about load pattern when, for example, having a tariff with load demand component. However, an important prerequisite here is that customer would have to have instantly available information on a device or screen, otherwise the feedback would come too late to expect changes in use.

It should also be mentioned that load curve could be a useful way to identify the operational problems when running the building.

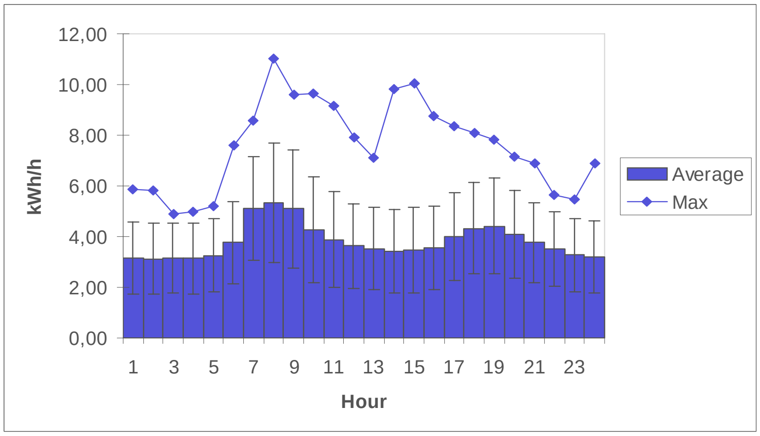
The load duration curve for the utility is essential information about customer's load demand, especially looking at the longer perspective (full year or season). A significant benefit given by the duration curve for the utility is that it directly shows the number of hours when the demand exceeds a certain load demand level, where there's the greatest need for load control actions.

Typical load curves

The typical load curve is different from the simple load curve as it is more than just a momentary visualization of electricity use. It normally shows the mean load demand value for each hour during the specified period (week, month, year, etc.). The typical load curves are often developed to compare the demand on weekdays and weekends. Figure 2 shows the daily load curve of one household for the winter period. The average and maximum hourly load as well as standard deviation is shown.

The typical load curve can be used for comparison of “typical” patterns and for a selected time the actual energy performance. This method therefore is useful both for customer and utility. It is a good graphical representation and clear picture of household-specific energy use and daily consumption pattern. The method provides valuable information for a utility for designing demand response strategies and new value-added energy services.

Figure 2. Daily load curve example



Load coincidence

Different customers naturally differ in the load curves/patterns. What principally matters for the utility is the total load pattern of all the customers – the coincidence load. The coincidence load curve should be as even as possible. This would be a favorable situation for the utility. The coincidence factor is the ratio of coincident load maximum value to maximum value of partial load demand (equation (1)).

$$CF = P_{max} / \Sigma P_{imax} \qquad (1)$$

where:
P_{max} = coincidence load maximum value,
P_{imax} = maximum value of partial load i.

This ranges between 0 and 1 as coincident demand should always be less than or equal to the maximum demand.

Load Factor

Load factor is simply the ratio of the average load during a specific period of time to the maximum load occurring during that period, as given in equation (2):

$$\text{Load Factor} = \frac{Load_{average}}{Load_{\max}} \qquad (2)$$

The load factor is used to demonstrate variations of the household's load demand. This factor can range between 0 and 1, where a value of 1 would indicate that the household load curve was completely flat and no peaks were present. From the supplier's point of view, it is preferable to remove peaks and flatten out the load curve, corresponding to an increase in load factor.

The load factor is a good tool both for utility and customer. However, the major shortcoming of the load factor is that it does not represent the magnitude of the consumption, i.e. the value of the highest load and average loads. For the utility, looking at just the load factor, makes it difficult to judge the load reduction potential for the specific customer and the influence on the total utility load.

The load factor can be used as a parameter when designing or analyzing new electricity tariffs. For example, it is a way to evaluate the load pattern before and after the introduction of a new load tariff.

Exploitation Time

The exploitation time provides information about the shape of the customer's load demand curve. The time, calculated in hours, represents the required duration of maximum (peak) load needed to correspond to the total actual electricity usage during the same period, which can be represented by the equation (3). A high exploitation time relates to an even load demand – a preferable situation for the utility (North 2001).

$$\text{Exploitation Time (h)} = \frac{\text{Electricity Consumption}}{Load_{\max}} \qquad (3)$$

Exploitation time has more value for the utility than the household customer as is more complex parameter than load factor and would not provide meaningful information for the customer.

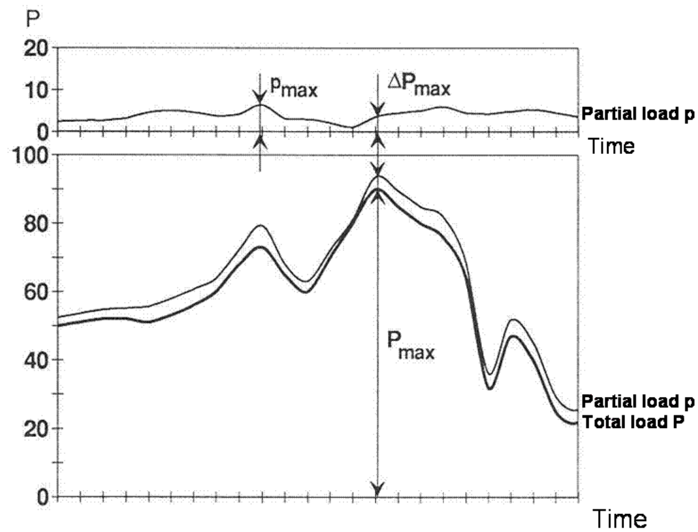
Superposition factor

Superposition describes one specific customer's influence on a total utility load curve or the contribution of partial load to the total load. Superposition factor is the ratio between the partial load demand during the total peak and the maximum partial load during the same time period as it is expressed in Figure 3 and equation (4).

$$SF = \Delta P_{max}/p_{max} \quad (4)$$

where:
ΔP_{max} = increase of total load peak value due to partial load **p**,
p_{max} = partial load maximum value

Figure 3. Superposition and superposition factor (Pyrko 2004)



Source: Pyrko 2004

The range of values that this factor can take is between 0 and 1, where a value of 1 would indicate, that the peak of the partial load coincided with the peak of total load. What the superposition factor doesn't tell is how big the partial load demand is that contributes to the maximum load of the system, doesn't tell the magnitude of the use of the specific customer.

Superposition factor is, of course, a more "utility oriented" tool. This factor could be the major decision driver to select customers for participation in DR programs. The factor identifies which customers should be addressed first and where the load management activities would actually give the desired results. Having this knowledge, for example, the utility could approach the specific customer, or group of similar customers, with the special proposals for DR actions (tariffs, load control programs, etc.). Obviously, it is necessary to look at many peaks to be able to determine if the peaks coincide by chance or if there is an evident correlation.

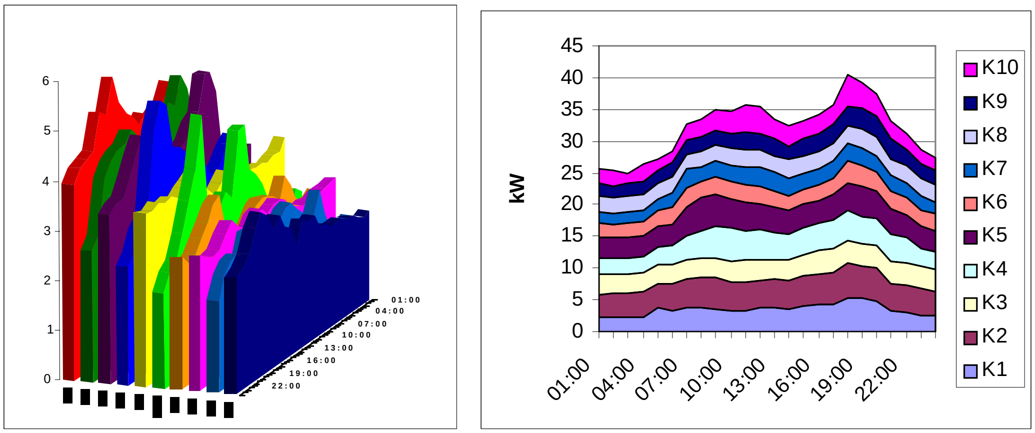
Examples of ten households

This study is exemplified with ten cases of households with electric space heating in Southern Sweden.

Our associated utility Skånska Energi AB has installed advanced metering system "CustCom" to all its customers (99% of those are residential houses)(Abaravicius, 2004). The system is able to provide automatic hourly measurements, as well as electricity control and information services. At the moment it is used only for measurements and billing purposes. Hourly use data is automatically collected by the utility and is available for each customer via Internet. The hourly data is available in form of tables and load curves during a specified period.

Figure 4 shows the typical daily load curves (average value during specific hour) and coincident load curve for the10 analyzed households during December 2003.

Figure 4. Households' typical daily load curves and coincident load curve during December 2003 (Sernhed 2004)



Source: Sernhed 2004

Table 1 shows an example of load factor and the exploitation time for 10 households in Southern Sweden calculated for period April 1, 2003 – Feb 15, 2004.

Table 1. Load factors and Exploitation time for 10 analysed households

Household	**Total consumption**	**Average load**	**Load Factor**	**Exploitation time**
	kWh	**kWh/h**		**h**
H1	16906	2,19	0,17	1339
H2	21910	2,84	0,24	1877
H3	16525	2,14	0,23	1798
H4	17506	2,27	0,22	1683
H5	18695	2,43	0,22	1698
H6	**13405**	**1,74**	**0,28**	**2128**
H7	**12757**	**1,66**	**0,29**	**2254**
H8	**13966**	**1,81**	**0,27**	**2060**
H9	11874	1,54	0,23	1770
H10	15422	2,00	0,22	1719

The example shows that households H6, H7, H8 have the highest load factors and highest exploitation times among the analyzed objects. From the load demand point of view, these customers could be seen as the most favorable for the utility. On the other hand, these households (together with H9) also have lowest total electricity consumption, and average load demands, that, in turn, decreases their significance for the total demand conditions of the utility.

Table 2 shows results of a superposition factor analysis performed for 10 households in order to observe which of them are mostly contributing to the utility peaks. The utility's ten highest hourly peaks within the analyzed period were selected and the superposition factors for the households were calculated. The results indicate that households H10, H4, H5, H6, H8 were mostly contributing to the selected utility peaks (SF ≈ 1,0). What superposition factor doesn't tell is how big the partial load demand is that contributes to the maximum load of the system.

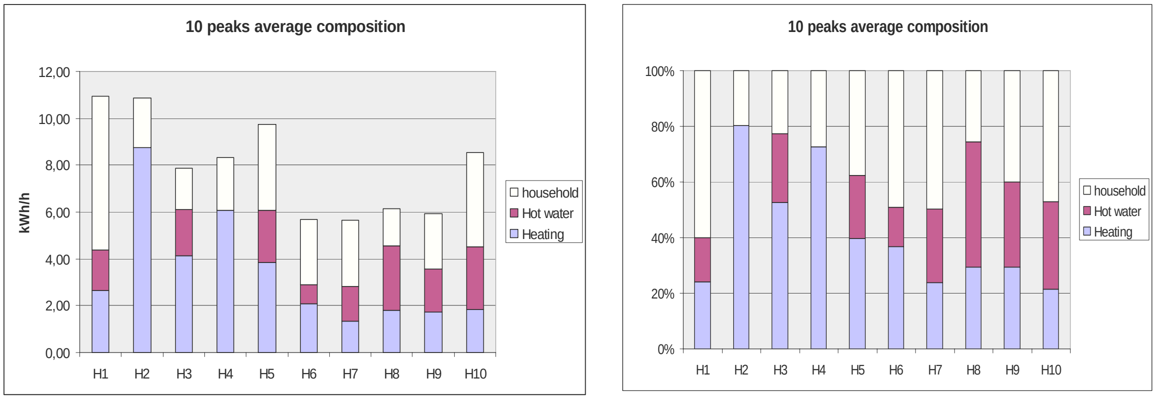
Table 2. Superposition factor for 10 analysed households

10 utility peaks												
date	**kWh/h**	**Out. Temp.,°C**	**H1**	**H2**	**H3**	**H4**	**H5**	**H6**	**H7**	**H8**	**H9**	**H10**
2004-01-22 08:00	80387	-15	0,81	0,95	0,81	**1,00**	**1,00**	0,65	0,66	0,91	0,81	**1,00**
2004-01-22 18:00	76400	-9	0,78	0,79	0,89	**1,00**	0,59	0,70	0,82	0,78	0,89	0,80
2004-01-21 19:00	74019	-8,1	0,69	0,66	0,92	**1,00**	0,75	0,56	0,74	0,88	0,70	0,73
2004-01-21 08:00	73773	-9,8	0,78	0,86	0,76	0,83	**0,99**	0,55	0,59	0,86	0,57	**0,95**
2004-01-26 18:00	72202	-3	0,75	1,00	0,90	**0,95**	0,81	0,68	0,78	**1,00**	0,60	0,60
2004-01-27 18:00	71429	-4,3	0,66	0,92	0,82	0,81	0,76	0,64	0,94	**1,00**	0,56	0,93
2004-01-05 18:00	71128	-7,4	0,81	0,91	0,83	0,59	**0,97**	**1,00**	0,85	0,79	0,68	0,93
2004-01-23 08:00	70934	-3	0,88	0,86	0,81	0,86	0,82	0,66	0,55	0,68	0,55	**1,00**
2004-02-12 08:00	70614	-4,3	0,31	0,80	0,73	0,87	**1,00**	0,72	0,79	0,53	0,65	**1,00**
2004-01-02 18:00	69494	-3,9	0,74	0,89	1,00	0,92	0,59	**1,00**	0,86	**0,97**	0,71	**1,00**

What's beyond the peaks?

For experimental purposes two extra meters were installed to measure load demand for heating and hot water. Figure 5 provides the overview of the average of 10 highest peaks of every household and the peaks' composition. The available metering of partial loads allows insight into the origin of the peaks, i.e. whether it is a climate dependent or behavior dependent peak. The composition is presented in two ways – in kW, in order to see the peak value and as a share of the load demand.

Figure 5. Ten highest peaks at the analyzed households



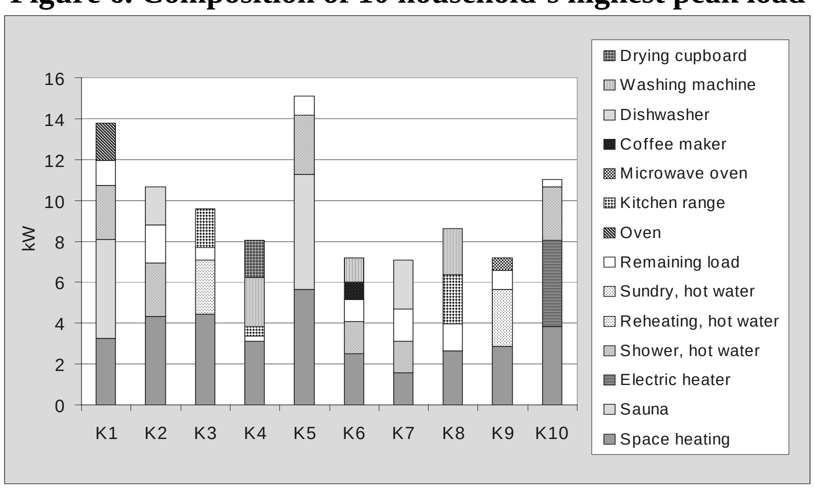
This information has primarily value for the customer as they could directly see what kinds of end-uses consume most energy. This kind of information could be treated as a specific utility service. It should be mentioned, nevertheless, that the method might be costly as it requires installation of extra meters.

The utility also benefits from this data as it provides good grounds and information to develop value-added energy services, as promotion of specific appliances, installation of storage and load control equipment, etc.

A very interesting and, in a way, unexpected result in Figure 6 is the electricity demand for household needs which can be as high as 60% of the total demand during some periods. Furthermore, these periods were measured during the winter season when one would normally expect the heating demand to take the highest share. The important conclusion therefore is that not only the climate (outdoor temperature), but the behavior related electricity use could be a serious cause of load peaks. Especially risky is the coincidence of both.

In order to get a more detailed energy use description, diaries were filled in for 4 days by household members. Based on this information and measurements it was possible to specify all end uses' contribution to the highest peak during the four-day period. The results are given in Figure 6 (Sernhed 2004)

Figure 6. Composition of 10 household's highest peak load



Source: Sernhed 2004

Heating load

The measured load data for heating could be extended to various outdoor temperatures using the *regression analysis*. This is a good tool for a utility to predict the demand related to temperature variation, as well as to estimate the expected load savings by controlling (turning off or partial decreasing) load for heating in load management programs. Heating systems are normally the primary subject for load management/control programs as they have highest load demands and could be manipulated with the least negative consequences for a customer.

One interesting idea to look into is if the separate measurement of heating load could create a possibility to charge it separately. Different contracts for heat supply in this case could be developed. Consequently, it could stimulate for instance the investment in heat storage technologies, system automation, load control technologies, etc.

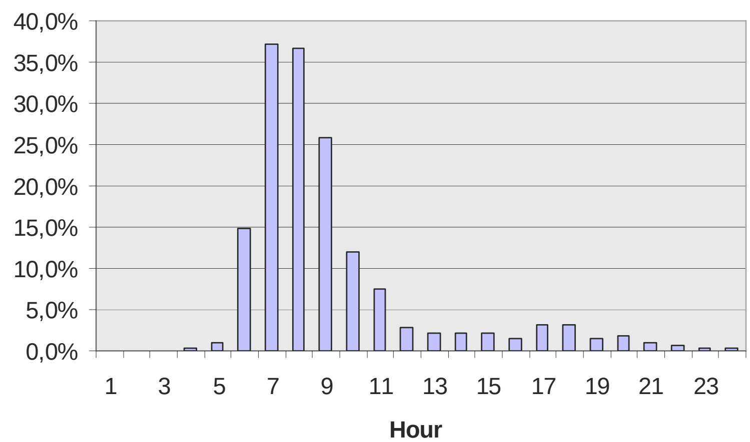
Hot water load

Hot water use has a tendency to increase during morning and evening hours in most households and thus contribute to the total load peaks. Similar conclusion could also be drawn from an analysis of probability that hot water boiler is on full power, presented in Figure 7.

An important question, when analyzing load demand for hot water, is when the hot water boilers are on full power. Having this knowledge it is easier to create load management strategies, as it gives a suggestion when to control the units in order to get a maximum load savings. Using the daily load curve and the hourly data, the following methodology for finding the probability if the hot water boiler is on full power was developed for our case studies: it is assumed that boiler is on full power if the hourly load exceeds 2,5 kWh/h. Every hour of the day through the investigated period is analyzed. Number of hours when the load reached this value is divided by the total number of recorded hours.

The result for one of the households (H5) is given in Figure 7. Values on Y axis show the probability (%) that the water heater is on full power versus the hours of the day (0-24). The pattern of load demand for hot water varies from household to household, principally depending on the behavioral factors. There is a tendency for the highest demand to occur during morning and evening hours, therefore these periods could have the highest potentials for load control.

Figure 7. Probability that hot water load is on full power during a day



Concluding discussion

New automatic meter reading technologies allow to measure more than the total electricity demand. High resolution load data is now available both for the customer and the utility. The open question remains how the data should be provided in order to make customer interested in better understanding their energy use? Is it sufficient only to make it available online? The research on this particular issue is on the way, however, it requires broad efforts and trans-disciplinary cooperation of engineers, economists and behavioral scientists.

The load analysis tools, touched in this paper, are not new. The novelty here is their use when analyzing residential load demand and their applicability in the residential market conditions.

Load curves, daily load curves, load factor, and superposition factor should be used as good representations of the household load demand. Load curve is more useful tool for the customer, while the duration curve is more useful for the utility. Load factor is a useful indicator both for the utility and the customer. However, the major shortcoming of the load factor is that it does not represent the magnitude of the consumption, i.e. the value of the highest load and average loads. For the utility, looking at just the load factor value makes it difficult to judge the load reduction potential for the specific customer and how would it influence total utility load. One interesting possibility is that the load factor can be used as a parameter when evaluating new electricity tariffs.

Even though ideal market development demands broad participation in DR programs, with the help of such a method as superposition, the utilities can start it with the households and their energy uses that contribute the most to their peaks.

Typical load curves provide valuable information for a utility for designing demand response strategies and new value-added energy services.

Partial loads measurement has primarily the value for the customer as they could directly see what kinds of end-uses consume most energy. This kind of information could be treated as a specific utility service. It should be mentioned, nevertheless, that it requires installation of extra meters. The utility also benefits from this data as it provides good information to develop value-added energy services, as promotion of specific appliances, installation of storage and load control equipment, etc.

Special attention should be given for the electricity used for heating (as the highest demand). One possibility is to measure and charge it separately. Different contracts for heat supply could be developed.

There’s evidently higher interest for the utility in analyzing load demand or, in another words, it is a utility oriented process. It provides a utility an essential grounds, sources to create appropriate DR strategies (pricing, direct control, etc.).

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VII

The 11th International Symposium on District Heating and Cooling,
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MAKE THE HEAT HOTTER!
- Marketing district heating to households in detached houses

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ABSTRACT

For district heating (DH) companies, to expand in low heat density areas such as detached houses, it is essential to obtain a high rate of connections to the district-heating network in order to enhance the cost effectiveness. Marketing district heating to villa owners is, however, a fairly different matter from selling it to customers in industrial, commercial, and multi-family buildings. Suitable market strategies need to be developed and the need for information about potential customers' preferences and attitudes are of great importance since the house-owners often constitute a heterogeneous group where different households have different requirements.

This paper investigates a case of one Swedish district heating company's marketing activities and expansion strategies in a single family house area where the customers were offered conversion of their direct resistive electric heating (DEH) into district heating (DH). 88 out of 111 houses were converted in 2002. Four years later, interviews were carried out with 23 of the households in the area, both with those who had accepted the district heating offer and those who had not.

The study shows that apart from the economic aspects, thermal comfort, aesthetics and practicalities also affected the buying decision. Since the different economic aspects of the offer were complex, it was very difficult for the households to make a strictly rational economical decision.

Statistical analysis confirmed that variables such as age, type of household and energy use level could, to some extent, be related to the decision to convert from electric heating to district heating. Timing, low prices and the total solutions presented to the households were crucial factors in the success of the marketing strategy.

INTRODUCTION

Background

Many district heating companies are unaccustomed to selling their services to single family houses. Up till now, DH companies have mostly invested in selling heat to bigger units such as blocks of flats and commercial buildings. For this reason there is a tradition to negotiate with commercial buyers. Selling of DH to customers in single family houses constitutes a new challenge. This is partly because this sector as a customer group requires different terms of sale and strategy, or because it demands a high rate of connection (i. e. many customers connected at the same time) within one specific geographic area.
Many companies can experience great interest among their customers in single family houses but because of an insufficient selling organisation and personnel, or inadequate capital to cover the expansion of the DH grid, they have problems to meet the demand at the pace it is created (Persson & Sernhed, 2004). Other companies may consider this sector not to be profitable enough as a customer segment. This can depend on the fact that these companies either have other possibilities to expand by selling DH to bigger customers, or on previous bad experiences from selling to customers in single family house areas.

Change of the space heating system from direct resistive electric heating (DEH) to DH means specially high investment costs for house owners because there is a need to install a new water borne system connected to the DH. All the investment costs taken together (excavation, connection, heat exchanger, etc) can be very high and must be weighted against other available heating alternatives. It is very important to keep the total investment costs as low as possible when converting a single family house from DEH to DH.

Over the last few years, many energy companies in Sweden have offered DH connections for their customers in villas and terraced houses. Among companies which have invested in conversion of houses with direct electric heating Luleå Energi AB och Växjö Energi AB can be mentioned (with connection rates 80-90 %). Similar campaigns were also performed in other Swedish municipalities as in Ljungby, Lidköping, Kristianstad, Boden and Sandviken, among others.

In Växjö, the local energy company Växjö Energi AB (VEAB) carried out many conversions of DEH systems to DH systems in several residential areas. A total package price for all the constituent parts (including change of the indoor heating system) was offered to potential customers. In one residential area with villas, in the urban district Sandsbro, Växjö Energi AB carried out conversion of 88 houses from DEH to DH. In the same area, there were another 24 households who decided to not convert. Expansion of DH in Växjö continues and according to the company Växjö Energi AB there is still a potential of a total of 2,000 to 3,000 single family houses within their concession area.

Objectives

The objective of this study was to investigate how households in a specific residential area in Växjö acted when their energy company offered them conversion to district heating. It was paramount to understand how the house owners deliberated and what arguments were behind their decisions to accept or refuse the proposal. It was also of great value to investigate the company's marketing and selling strategies. This study is focused on one specific villa area in Växjö.

On the whole, the aim of this project was to contribute to the knowledge and better understanding of the conversion process in order to improve DH companies' selling strategies, when offering DH to single family house owners.

PRODUCT OR SERVICE

District heating is somewhat difficult to define as a pure product or service. The question is what is included in the DH conversion proposal. When a villa customer is connected to the DH grid, installation of the DH substation is the main condition for heat delivery. These parts should probably be seen as 'products' (as boilers, heat pumps etc). The heat delivery itself has the characteristics of a 'service'. So what is the customer buying? This must depend on the kind of heating system that was originally installed in the house and what experience the household has already had of different heating systems.

When converting from DEH, the owner has to invest in completely new water borne system to circulate the heat in the house. Obviously, this installation causes an extra cost but can also create a higher indoor comfort for the household, which from the customer's point of view can be treated as the natural positive quality of DH.

LONG-TERM INVESTMENT

The heating system must be seen as an object of investment and not as an object of consumption – partly because of a substantial initial cost, and partly because of a long life-time, in some cases 20 years or more. Therefore, the time of making the decision of buying a new heating system is very important for marketing and selling strategy. Preferably, the households where the DH is offered should have an urgent need to change their heating systems. Hallin (1989) says that the households often wait to the very last minute with their decisions. In some cases this happens even if it would be more profitable for them to change the system earlier.

It is possible that younger households have a different attitude towards investments in new equipment. Contingently, additional factors, such as for example environmental issues, could influence the households to change the heating system.

URGENT ISSUE

A common motive to say 'no' to DH is a recent investment in a new heating system (Henning & Lorentz, 2005).

About half (49 %) of single family houses built in Sweden between 1971 and 2004 have solely electric (DEH or water borne) space heating systems (SCB, 2005). According to a study carried out by Mårtensson (2005), approx. 75-80 % of villas and terraced houses built after 1975 and sold between 1981-1995, are electrically heated. Many of the families living in these houses have today obsolete heating systems.

This means that there is a big potential for DH companies to convert these houses to district heating but this 'window of opportunity' is very tight - the change should be performed in the near future. The competition from heat pumps sellers, whose share of the market is increasing, should speed up activities undertaken by the DH companies.

In order to attract customers who have just bought a heat pump, a new boiler or water heater, DH companies should offer different solutions that still make conversion to DH attractive. One possible way to do this is to compensate households for recent investments and offer different flexible solutions as a help - for example by buying back a new boiler or fuel reserve (Persson & Sernhed, 2004).

CHOOSING THE HEATING SYSTEM

Isaksson (2005) describes in his review of households' relation to energy, several factors that are important when choosing a heating source in single family houses.

Experiences of previous systems and opinions with regards to comfort and convenience have a clear effect on the decision making process (Klintman et al, 2003; Henning & Lorentz, 2005) but, of course, attitudes can change when the new system is installed and operating.

An important factor is a household's lifecycle and present situation. Younger households often have financial limitations. With rising incomes, families establish and move to bigger dwellings. This often leads to higher vitality - many energy related decisions are made during this period (Isaksson, 2005).

In everyday life, the costs of the heating system are competing with other household expenses. Investment cost, pay-off time and energy prices (current and expected) influence our choice of a particular heating system. Some of the households prefer a low operation cost while others choose low initial cost.

Many studies show that 'word of mouth' (opinions and claims from family and friends) can be an influencing factor to both choice and usage of heating systems (for ex Henning, 2000: in Isaksson, 2005).

THE CUSTOMERS' DECISION INVOLVEMENT

The change of the space heating system sometimes constitutes a very big decision for a house owner.

Within communication research 'decision involvement' is defined as a mental condition of an individual that describes the relation between the person and object in his imagination (Palm, 1994).

The grade of involvement is of great importance when marketing a product or a service. According to Krugman (1965; in Palm, 1994), extremely low involvement impairs our attention on arguments of why we should buy the promoted product.

That said, research results show that it is sometimes fruitful to try to aim to create a lower decision involvement.

”High decision involvement means that the decision appears as important, that making the wrong decision may constitute a risk. (…) this can lead to the rejection of the decision is or postponement for an undefined future”.

”Low decision involvement means that the decision is not important at all, that the difference between doing things according to the decision and not doing them is negligible.” (Palm, 1994, s. 94)

Messages intending to lower decision involvement are characterised by giving a lot of '*how*'-information. Trying to decrease decision involvement when customers in single family houses are making a choice between 'yes' or 'no' to a DH proposal could be a possible strategy for a DH company.

DH COMPANIES' STRATEGIC MARKET PERSPECTIVE

A company can choose between different strategic perspectives (approaches) depending on what relation they have to the product or service they sell (Grönroos, 2002):

- A 'base product' perspective: This means that the quality of the base product is considered as a unique selling point (USP).

- A 'price' perspective: This means that the company treats low prices as USP in the market competition. The risk with this approach is that this market advantage will disappear as soon as another company offers a lower price.

- An 'image' perspective: In this case, a company tries to use marketing in order to create new values in addition to the base product. This extensive market communication should be performed continuously and can be very expensive.

- A 'service' perspective: This means that a company considers that services connected to customer relations have a strategic importance, whether they are products or services.

Grönroos (2002) recommends a transition to a more service focused perspective, even for companies whose base activities are directed towards products. He means that competition on service has become a reality for many companies today. Those who are not involved in this process may experience growing problems and difficulties. Today, the service perspective has become a given rule, which means that DH companies have to revise their whole communication strategy, from base product to service choice, including a customer call centre.

In Persson & Sernhed's study from 2004 about DH companies' sale strategies in single family dwelling areas show the kind of information that is collected by the companies about their potential customers. Over 60 % of the investigated companies have a lot of knowledge about houses and installations, i e physical parameters. Compared to this, the knowledge about social factors is significantly lower, for example about the residents' profession or age, or totally absent (education and income). One exception is information about the number of family members (household structure) – 18 % of investigated companies have access to this – mostly likely with the aim to calculate customers' hot water demand.

One distinct conclusion from this study is that Swedish DH companies still treat their customers more as 'heat loads' than *customers* with different preferences and needs. This also means that these companies have a very bad understanding about their current (and potential) customers' way of thinking and making energy related decisions.

DIFFERENTIATING PRODUCT/SERVICE DH

The market for space heating in single family houses is competitive. While DH companies are trying to attract new customers, they should keep in mind that DH is a long-term, site-bound business. Thus, they should not openly jeopardise their name by short-term measures. One of the recommended methods is to differentiate DH for the customers.

Kotler et al (1996) defines it as follows:
"Differentiated marketing: A market-coverage strategy in which a firm decides to target several market segments and designs with separate offers for each."

An important issue when selling DH is that all the customers within one specific area are willing to connect. Because there is no possibility of customer segmentation, flexible solutions, each fitting different customers, should be offered.

There are some examples of DH differentiation by means of price models and (to some extent) value added services.

Wirén (2005) suggests five different price models for single family house customers:

- Price model 1 – There is no connection fee. The DH company owns the installation and is responsible for the operation, maintenance and reinvestment. The customer pays a fixed standing charge and variable energy unit charge.

- Price model 2 – There is a partial connection fee covering the DH sub-station and the installation. The customer owns the heating system and is responsible for its operation, maintenance and reinvestment. The company offers different service packages.

- Price model 3 – There is a single total fee covering all the costs for DH connection. The customer owns the heating system and is responsible for its operation, maintenance and reinvestment. The company offers different service packages.

- Price model 4 – There is a connection fee depending on a decided fixed amount of heat. The customer owns the heating system and is responsible for its operation, maintenance and reinvestment. The company offers different service packages.

- Price model 5 – The company offers a connection fee with a variable energy unit charge that is equal to 1/3 of the electricity price. This pricing is intended to meet the competition from heat pumps sellers. The customer owns the heating system and is responsible for its operation, maintenance and reinvestment. The company offers different service packages.

Mårtensson (2006) gives some additional examples of pricing and services (for example district cooling supply, snow melting, heat supply in case of power shortage or energy saving tips) that can differentiate DH for customers in single family houses:

Offering DH as a total solution in complete packages has also been used as a successful way to convince new prospective residential DH customers.

SOME CONCLUSIONS

- The time is ripe to convert to DH at the moment: partly because many houses, built during the 70s and 80s are coming up for change of the heating system, and partly because the competition from heat pumps can undermine the district heating market (as the connection rate will be too low in areas where many households have already installed heat pumps).

- The timing of the DH offer is an important factor in selling strategy to single family houses, as it is entirely dependent on where the household is in its lifecycle.

- In order to attract those households who have recently invested in a new heat pump, boiler or water heater, special strategies are necessary to convince them that the conversion to DH is still worthwhile.
- The change of the space heating system equates to a high level of engagement, while the delivery of the distinct heating itself demands a low engagement level.
- A service-led approach could help DH companies to create 'value added' services for their customers.
- Clearly, there is a difference between selling DH to commercial and private buyers. Notwithstanding this, many DH companies collect insufficient data about their single family house customers. A service-led approach demands an in-depth knowledge about the customer base a well-developed 'relationship' with the customer.
- DH is a product/service which is very difficult to differentiate, but there are many advantages in applying varying price models, different types of 'value add' services or in focussing on potential environmental benefits.

INVESTIGATION

Field

This study, carried out at the Lund University (Sernhed & Pyrko, 2006), was initiated by the energy company Växjö Energi AB (VEAB). VEAB is an affiliated company to Växjö Kommunföretag AB, owned by local municipality Växjö Kommun.

The residential area Sandsbro in Växjö was chosen for this project. In this area, 112 houses were offered conversion to DH. 88 houses accepted the offer, and 24 said 'no'.

Four years after the conversion was completed, this study was carried out. At the time of the study, the average age of the residents in this area was 54 years, calculating only with the oldest members of each household. There was a clear top at the age of 61.

METHOD

Qualitative methods, based on semi-structured interviews with a sample of households from Sandsbro, were chosen to meet the objectives of this study. Specific data about families living in every house was collected as background information: age of the residents, year of moving in, heat consumption 2002 and electricity consumption 2001.

Interview objects' selection

The choice of households to be investigated was done based on data collected about the residential area in Sandsbro. First of all, it was important to differentiate the households that accepted the offer and those who had not.

It was of extra interest to know the reasons why some of the households refused the DH conversion offer. 13 households of the 88 who accepted the offer and 10 households of 24 who rejected it were chosen for the interviews. The choice of the 23 interviewed households was made regarding type of household, housing period and the household members' age.

One of the houses, belonging to the VEAB employee, was used as a show object. This household was included in the interviews and supplementary questions were asked about the demonstrations.

Interviews

An information letter was sent to all the households in September 2005. The interviews were performed during 4 days in September and October. In 21 of the households, the interviews took place in the respondents' homes. The interviews were recorded and transcripted. In one case, when recording was refused, notes were taken. The same procedure was applied during telephone interviews with two other households.

Statistical analyses

Some statistical analyses were conducted on the data obtained from VEAB about all the 111 households in this area. This means that the results can be generalised to the whole DH conversion area. However, one should be more careful to interpret the conclusions to households outside this area because the analyses were not performed on a random sample of a larger population.

DISTRICT HEATING OFFER

The 'trigger' for district heating expansion in Sandsbro was an inquiry from the Swedish Energy Agency to the Växjö Energi about the participation in a trial project where some simple and easy solutions to convert heating system to DH would be tested. In this case, only electric heating systems were of interest. This project started because of an immediate possibility to apply for a conversion subsidy (20,000 SEK per household) the same year.

Complete package

VEAB offered the households in Sandsbro a total solution including DH grid connection, conversion to water borne space heating system and DH sub-station.

The following items were included (according to the information from VEAB):

- Water borne system
- Visible pipes painted white
- Complete DH installation
- Dismounting of old radiators
- Disconnection of electric cables
- One new socket per radiator
- Hanging of new radiators, including thermostats
- Lower fuse – 16 A

Painting, papering and final cleaning were not included.

Price

The price for the whole package was 79,000 SEK for the connection rate of 50 %. The higher number of connected houses, the higher was the reduction of the final price, as shown i Table 1.

Table 1. Prices at different achieved connection rates.

Connection rate	Reduction (SEK)	Price (SEK)
50 %	0	79,000
60 %	1,000	78,000
70 %	2,000	77,000
80 %	3,000	76,000
90 %	4,000	75,000
100 %	5,000	74,000

Due to the final connection rate in this area of approx. 80 %, the reduction for each household was 3,000 SEK.

The households had even some possibilities to lower the final price if they did their own work:

- Excavation work could reduce the price by 300 SEK per meter.
- Dismounting of old radiators - 600 SEK per house.
- Hanging of new radiators – 1,500 SEK per house.

A governmental conversion subsidy (20,000 SEK per household) could be obtained after an application to the county administrative board. Personnel from VEAB helped the households with this procedure.

Guarantee

A two years guarantee was given in the contract, which is a normal guarantee time for this kind of installation, according to the regulations of sale.

Extra service

DH company was obliged to lend a water heater (at cost price for the installation) if the customer's old heater would be out of order during the DH conversion.

SALES PROCESS

Activities

VEAB started its sale activities in Sandsbro in June 2001. The sale process consisted of the following steps:

Mailing 1

In June 2001, the first letter about DH conversion was sent by VEAB to the households in the area. A meeting about the whole offer was announced.

In the next letter, a preliminary price of 59,000 SEK (including the conversion subsidy) was specified.

A brochure about district heating and its benefits for the customers was attached. A non-binding expression of interest could be sent back to the company.

In the middle of August, an invitation to two alternative meetings was sent promising more information prior to the meetings.

Information meeting

Two information meetings took place. More facts about prices and conditions were presented.

Mailing 2

Shortly after the meetings, a new letter about the formal decision to start DH conversion was sent. New (binding) application forms could be signed and send back to VEAB. The applicants were reminded about the conversion subsidy procedure. Households who did not send their expression of interest to VEAB could still do it.

Show house

One house was prepared as a show house to display a 'real' district heating system (temporarily driven by an electric boiler). A four-colour leaflet informed the visitors about the DH conversion and showed different types of connections and pipes, both horizontal and vertical.

Home visits

In November 2001, letters were sent to the households about a home visit of a technician from VEAB. The objective of this visit was to discuss radiators and pipes placing, and to decide some special solutions. Correction of the price depending on own work and extra choices was fixed. The final binding contract was often signed at this occasion. Only the household that sent preliminary expression of interest were visited.

Excavation

Excavation started in January 2002 and all the installation was completed at the end of summer the same year. Several sub-contractors were engaged in this work. A few households used the possibility to reduce the final price by own work.

Conversion

Parallel with the excavation, converting activities were carried out in the houses. Some of the operations could be done by the household owners themselves.

Final activity

After summer 2002, the DH converting process was finished and all the customers were invited to a 'meet and greet' evening. Some gifts were distributed to the participating households.

RESULTS AND RECOMMENDATIONS

Households' reactions to the terms of sale and conversion

- Many households felt that the decisions were rushed - there is a need for better planning, especially for the older households.

- The information provided was evaluated as detailed and sufficient.

- The "demonstration villa" was a good idea but the installation should be done more professionally - aesthetics are very important here.

- Home visits were the only personal contact and should be conducted in all houses in order to answer questions and explain problems.

- Co-ordination of excavation should be better, in order to limit the time the ground is open.

- A few of the households undertook some of the works themselves to reduce costs but the compen¬sation was often considered as too low to motivate customers.

- All the parts of selling process create customers' total opinion about the process and the offered product/service. It is crucial that all the involved sub-contractors contribute to a positive overall impression.

Household' opinions on the product and/or service

- Almost all households felt that the thermal comfort was better than before - more stable indoor tempera-ture, no problems with overheated radiators or smell of burning dust.

- On the other hand, hot water comfort was worse - longer waiting time for hot water and too low water temperature during summer.

- Aesthetics were considered very important and could be crucial for the decision to convert the heating system.

- Many of the interviewed households were uncertain how to adjust and take care of the system - there is a notable need for information here.

Households' understanding of the economic terms of the DH conversion

- It was clear that many of the interviewed households did not have a view about the change of energy costs after conversion. It was also difficult for them to make a profitability analysis before the decision. However, the offer was considered to be very favourable in this specific case.

- It is important that the offer and investment comes at the right time for the households - regardless of the price.

- One argument raised against district heating conversion was fear of monopoly and high energy costs.

- All households, even those not converted, were convinced that the investment would be paid back in the future because of an increased property value following conversion.

- There is a limited knowledge about the cost savings made by the customers. This information is important in order to get confirmed that the decision to convert to DH was correct and profitable.

- Many households, even these who did not decide to convert to DH were convinced that the price of the house will rise in the future because of DH system installation. This can be a very strong argument when promoting DH in new residential areas.

The interview answers gave us some concrete reasons why the customers had accepted or refused the DH offers:

Reasons to say "no" to DH conversion

- The household has recently invested in a new heating system or in a secondary system,
- Negative views about aesthetics of the waterborne system,
- It's too labour intensive to convert,
- Wrong facts or misunderstanding.

Reasons to say "yes" to DH conversion

- Improved thermal comfort,
- Convenience,
- Low investment costs
- Expectations about lower energy costs,
- Few alternatives to direct resistive space heating,
- Better than electricity from an environmental point of view.

Statistical analyses proved that variables such as 'age', 'type of household' and 'energy use level' could, to some extent, be related to the decision to convert from electric radiators to district heating.

One result needs a special comment – among the older households there was a fairly large proportion of those who didn't convert to DH. Although old age cannot be a determining factor here, it is notable that within this group DH companies are loosing many potential customers. In some of the interviews, the older respondents complained that the decisions were too rushed – more time and long-term planning was needed. This customer group claims much more concern and probably needs a special way to be introduced to DH.

It is important to remember that all the efforts put on selling campaign will create new customers buying heat for many years ahead. So far, the DH customers have been very loyal to the heat suppliers. This condition does not have to be permanent in the future.

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