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Disaggregated Electricity Feedback

An analysis of the conditions and needs for improved electricity feedback in houses

Jonatan Ståhlberg

UPPSALA
UNIVERSITET

Teknisk- naturvetenskaplig fakultet
UTH-enheten

Besöksadress:
Ångströmlaboratoriet
Lägerhyddsvägen 1
Hus 4, Plan 0

Postadress:
Box 536
751 21 Uppsala

Telefon:
018 – 471 30 03

Telefax:
018 – 471 30 00

Hemsida:
http://www.teknat.uu.se/student

Abstract

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This thesis examines if house-owners are prepared to reduce energy use by means of accessing more information on electricity consumption. The goal has been to examine whether house-owners are interested in details such as knowing what impact various installations and electrical appliances have on the overall consumption, and to present examples of various solutions available for solving this task. The aim has also been to present recommendations on what features such a system should hold, and to suggest how it can be designed.

An orientation has been made on the electricity metering market for electricity trading, to examine what information is available to households today. Research in the topic of electricity feedback suggests that today's public methods are generally not as effective as other solutions with greater saving potential. The concept of Disaggregated Electricity Feedback (DEF) has been introduced and is intended to give effective feedback, contributing to a better understanding of the household electricity consumption. Study's main goal has been to investigate house owner's interest in what DEF is aiming to achieve. The results show there is a strong interest for house-owners having access to what DEF is supposed to provide. Another result obtained in this work is that a potential product equipped with the DEF may be of interest to other parties. With technology changes taking place in the electricity market, opportunities are created for electricity companies to offer their customers completely new and customized services, where a DEF-product may have a number of possible uses.

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Sammanfattning

Detta examensarbete ämnar undersöka betydelsen av att minska energianvändningen i bostadshus och om vanliga husägare är beredda på att minska denna genom att få tillgång till mer information om elförbrukningen. Det finns många hus som förbrukar stora mängder el, särskilt i Sverige, med stora besparingsmöjligheter. Målsättningen har varit att undersöka om husägare är intresserade av att i detalj få veta mer om vad olika installationer och eldrivna apparater har för inverkan på den totala förbrukningen. Det har även presenterats exempel på olika system och metoder som finns för att lösa denna uppgift. Målsättningen har även varit att ge rekommendationer för vilka funktioner ett sådant system bör ha, samt ge förslag på hur systemet kan utformas.

För att kunna undersöka detta har en orientering gjorts kring hur elmätning vid elhandel fungerar idag, samt vilken information som finns tillgänglig för husägare och övriga personer i hushållet. Under examensarbetets utförande har även forskning inom området granskats. En minskad elanvändning kan ske genom att få tillgång till mer information om elförbrukningen, vilket är det första steget mot en bättre medvetenhet. Men även hur denna information presenteras är viktigt för att hushållen ska ta till sig informationen. Forskning talar för att dagens allmänna metoder i regel inte är lika effektiva som andra tänkbara, där besparing på upp till 15 procent av hushållselen är möjlig genom att få en snabbare återkoppling av elkonsumtionen. Med hushållsel menas den el som i ett hus används till belysning, vitvaror, apparater och annan elektrisk utrustning. I snitt används 6 000 kWh för hushållselen i ett hus per år, vilket enligt den givna besparingspotentialen skulle medföra upp till 900 kWh i årliga energibesparingar.

Konceptet *Disaggregated Electricity Feedback* (DEF) har införts och är tänkt att genom effektiv återkoppling, som kan bidra till en bättre förståelse av hushållens elkonsumtion, kunna ge bättre förutsättningar till att minska elförbrukningen. I hus där elkonsumtionen är stor kan DEF göra mest nytta, och tanken är att det ska ges detaljerad och användbar information om all elförbrukning och inte enbart hushållselen. Studiens huvudsakliga uppgift har varit att undersöka husägares intresse för det som DEF syftar till att åstadkomma, och därför togs i ett tidigt skede beslutet att en kundundersökning skulle genomföras med urval av husägare. Resultatet av kundundersökningen, där urvalet av husägare skedde enligt vissa uppsatta kriterier, visar att det finns ett starkt intresse för husägarna att få tillgång till vad DEF är tänkt att tillhandahålla. Anledningarna till intresset varierar mellan olika husägare. Det råder dock ingen tvekan om att en tillgång till kontinuerlig och specifik information om husets elförbrukning, med en uppdelning från och med per rum och vidare ner på vissa apparater, är något som husägarna ser som något positivt.

Ett annat resultat som erhållits i detta arbete är att en potentiell produkt utrustad med DEF kan vara av intresse även för andra parter. DEF har flera tänkbara användningsområden förutom att underlätta för elkonsumenter att spara energi och pengar. Slutanvändarna är husägare, vilka även har undersökts närmare i denna rapport. Men i och med de teknikförändringar som just nu sker på elmarknaden skapas möjligheter för elbolag att erbjuda sina kunder helt nya och kundanpassade tjänster, där en produkt utrustad med DEF kan uppfylla flera tänkbara funktioner.

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1. Introduction

This chapter provides the reader essential background and disposition of the thesis work. An introduction to the subject is given followed by the purpose, research questions and scope of the study. The chapter ends with a brief presentation of the outline, and commonly used abbreviations as well as some clarifications.

1.1 Background

Energy use and depleting of the earth's recourses is frequently debated all over the world. Governments and public authorities are working intensively in reducing energy use and emissions, including not only industrial and transport sectors, but also the buildings we use and live in. Energy efficiency is also to be adapted in the households, not only affecting building design, but also housing patterns and to be part of people's everyday lives. In Sweden, together with many other European countries, the building stock accounts for about one third of the total energy use, with great potential reducing both energy use and energy costs.

In the challenge of reducing energy usage in building sectors, a good deal have so far involved solutions with new building technologies and automation. More and more, however, it is being suggested that the reduction of energy usage is not likely to be made solely through technical means, as it will necessitate economical and social means as well. Laws that include all citizens do affect from the moment of implementation, in the addition of conventions and practices that affect the development of society in a more concealed way (Ellegård & Palm, 2008). An energy using sector with a large number of users will obviously need lots of small changes on the individual level to achieve considerable improvements. Systems based on automatic control engineering have for a long period of time given advantages for industries and larger buildings in the residential sector. With increasing energy prices regular homeowners are likely to hold an economical incentive on lowering energy bills, but the majority of the residential sector still faces barriers due lack of information, support and incentives. Most importantly households have for a long time acted energy users in the absence of sufficient energy feedback.

Domestic energy consumption is still largely invisible to millions of users and this is a prime cause of much wastage. Feedback on consumption is necessary for energy savings. It is not always sufficient – sometimes people need help in interpreting their feedback and in deciding what courses of action to take – but without feedback it is impossible to learn effectively.

(Darby 2006, 17)

In most households information on energy use is hidden, aggregated and delivered in a complex way. Energy users are therefore likely to behave in a manner of passive consumption, being unaware of what consequences are caused by their own usage. Consumers are rarely given opportunities to learn and provide input for investing in efficiency measures, or apply conservation strategies in their everyday lives. Even if technological development with less power rate on new appliances is continuously achieved, we can not ignore the importance of consumers' attitudes, choices and living habits.

Feedback is strongly believed to be of importance in making electric energy more visible and more amenable to understand and control in households. According to Darby, energy feedback is useful as a self-teaching tool with ability to improve the effectiveness of other information and advice in achieving better understanding and control of energy use (Darby, 2006). New electricity metering technology with an opportunity to provide detailed information about electricity consumption has a potential for improving energy awareness.

Researcher and lecturer Liikkanen points out the importance of designing new information and communication technologies so that inhabitants receive the right kind of information or feedback. This is crucial if the feedback concerns improving the energy awareness, thus the importance of feedback being coupled with some product or service that the user finds useful. Instead of helping and supporting, poorly designed products can be useless or even mislead users risking to increase the electricity consumption if it signals that you can safely consume more than you do now (Liikkanen, 2009).

This thesis is made closely connected to a project which intends to examine future market opportunities. The thesis tries to identify the problems with electricity information and examine what methods or solutions on energy feedback are being used today. The concept of Disaggregated Electricity Feedback (DEF) has been established during the project period, which has the purpose of presenting detailed information on the electricity use in households. Any product with the ability of improving energy use has great potential of bringing social benefits. The uses as well as the willingness, of implementing DEF are investigated for end-users. This gives input on if DEF is an option to make improvements in reducing costs and energy usage in the household sector among houses.

Even if a potential commercial product with DEF is intended for the end-users, the households, there is no certainty that this group is the only possible and most suitable customer. In this study, it is mostly discussed what opportunities may be provided with DEF, but also to some extent, the obvious obstacles that may occur.

1.2 Purpose

The study aims to examine if energy feedback is of importance for property owners trying to reduce energy use within their households. The energy feedback solution focused on is the concept of Disaggregated Electricity Feedback, with the aim of contributing to a complete market research that will determine the possibilities of a future market implementation. The purpose of this project is to explore the characteristics that are important for Disaggregated Electricity Feedback to win the acceptance of end consumers and households.

1.3 Problem formulation

To fulfill the purpose of the study the following problem formulations has been identified:

- How is energy usage distributed within households?
- What measures can be done to reduce energy usage in households?

The above questions are needed to achieve underlying perspective in the research field of the study. These questions are answered in the first part of the study.

- What standard meters are installed in houses at present and in the near future?
- How much information regarding electricity consumption can households obtain by the standard electricity meters?
- What rules and regulations are prescribed on electricity metering in households?
- What is Disaggregated Electricity Feedback and what other methods on energy feedback are being used in households?

Investigating these questions is in accordance with the purpose of the study. Some answers are proposed in Chapter 4 and 5, and further analyzed in Chapter 7.

- What is the property owners' interest towards Disaggregated Electricity Feedback?
- What is the future view of Disaggregated Electricity Feedback solutions?

These are the final questions the study is attempting to answer, and is mainly discussed in the concluding part of the thesis.

1.4 Delimitations

A complete market research may need to explore an entire network of operators or stakeholders, such as customers, shareholders, suppliers and other business partners, competitors, various organizations and agencies. This report sets its focus on potential customers, but does also include a required examination of the rules and laws, agencies and potential competitors. Focusing on customers there are many possible problem areas to investigate, such as habits, consumption behavior, values, pricing and design. This report does not provide any technical details, for instance measurement uncertainty or error intervals, of a fully developed product. The report primarily rather discusses the concept of DEF, which has been established during the project period, to be tried on selected property owners. Investigating the concept will nonetheless to some extent include the problem areas of, for instance, consumption behavior and values, for potential customers.

The geographical limitation of the study is an open issue. Primarily, the electricity and electricity measurement market is examined for Sweden in more detail, but essential information on developments in the rest of Europe and the US is also given. The latter is to obtain a perspective on what is happening outside Sweden, and is not involved in the main conclusions around the investigation of property owner's interest in towards improved energy feedback. The customer survey is made with Swedish homeowners, and any possible general conclusions drawn can only refer to these and after the criteria established.

1.5 Outline

- **Chapter 1**: Provides an introduction for the topic, and an outline of the thesis purpose and scope of the thesis.
- **Chapter 2**: Provides the approach in order to fulfill the thesis purpose.
- **Chapter 3**: Provides a necessary underlying background for the study.
- **Chapter 4**: Deals with the situation on regulations and directives relevant for the study.

- **Chapter 5**: Presents current situation of electricity metering and the different possibilities of providing energy feedback.
- **Chapter 6**: Presents the results given by the customer survey.
- **Chapter 7**: Presents a discussion of the results.
- **Chapter 8**: The thesis is ended with the main conclusions obtained during the study.

1.6 Abbreviations and clarifications

The following abbreviations are used in the report. Some important concepts are also identified and defined.

Abbreviations
AMR – Automated Meter Reading
AMM – Automated Meter Management (More advanced than AMR)
DEF – Disaggregated Electricity Feedback
DSO – Distribution System Operator (The electricity network company)
EDF – Électricité de France
ESMA – European Smart Metering Alliance
EPC – Energy Performance Certification
EU – The European Union
EU15 – Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and United Kingdom
EUROSTAT – The Statistical Office of the European Communities
DRSG – The Demand Response and Smart Grid Coalition
DSM – Demand Side Management
GSM – Global System for Mobile communications
GPRS – General Packet Radio Service
HAN – Home Area Network
IVA – Swedish academy, Kungliga Ingenjörsvetenskapsakademien
kWh – Energy unit in kilowatt-hour
LED – Light Emitting Diode
NIST – US National Institute of Standards and Technology
OEM – Original Equipment Manufacturer
PLC – Power line communication
RF – Radio Frequency
SAMS - Svenska Mätsamarbetet, consortium of 33Swedish DSO's
SEK – Swedish krona, currency of Sweden
SWEDAC – Swedish Board for Accreditation and Conformity Assessment
US – The United States of America
VAT – Value Added Tax

Definitions
AMR roll out – The launch, implementation or expansion of AMR
Cost-effective measure – An energy efficient measure, which despite the investment and maintenance cost on behalf of the savings in energy costs will result in lower costs than if it would not have been done

Direct electrical – Conversion of electricity to heat in electric radiators
Electric boiler – Conversion of electricity to heat in an electric boiler
Energy efficiency measure – Measure aimed at reducing a building's total energy use without compromising the indoor environment
Heat pump – Conversion of electricity through a work process
Household – A family or another group of people who are living together, but it can also consist of just one person
House-owner – A person who has the ownership responsibility for a private house
Load control – A way of ensuring the electrical load is less than what can be generated, and to avoid high electricity peaks
Nord Pool – The Nordic electricity exchange

2. Method

The following chapter describes the practical approach in relation to the theoretical framework selected. The thesis has, however, no intention of proving or discarding any theories since it is mainly an empirical study, hence for the most part the chapter deals with how different data have been collected. It gives a presentation of the method used in the study involving research motive, data collection and selection of investigated property owners. Lastly but not least importantly, a part with criticism of the sources is presented.

2.1 Research motive

Applied research is usually viewed as to solve practical problems of the modern world. If basic research is a systematic and methodical search for new knowledge and ideas with no specific application in mind, applied research can be of similar character but with a specific application in mind (Nationalencyklopedin 2009). According to Lawrence Berkely National Laboratory a trend of shifting in emphasis from purely basic research toward applied science is necessary, by reason of the problems resulting from global population, pollution and overuse of natural resources (Lawrence Berkeley National Laboratory 2009). The results of this project are primarily thought of as applied research since it also involves marketing research.

A market research serves as one of many different types of market information sources for any company or organization. What distinguishes the information in the marketing research from other information is that it has been systematically collected, analyzed and interpreted by reference to a specific and defined marketing problem. A marketing problem can however equally well be designated as a marketing opportunity. Usually, the research can contribute to a part of a larger decision-making, and can be of great help to understand the market and its operators. By creating an understanding of why the market acts as it does, a company can better align its business to different market needs (Andersson, et al. 2001). The supervisors of the project have the intention of developing some practical application, adding the results of this study to a complete marketing research. Any complete market research should possess the following seven steps:

- Problem analysis – By carefully analyzing the problem, one can define the problem so that it becomes possible to investigate. Then it can be determined what the purpose of the investigation should be.
- Methodology – This step is where it is determined how data and market information will be collected to solve the problem.
- Selection – If the information is already on the market, the targets for investigation must be determined.
- Data collection – The information is collected by any suitable form of data collection technique.
- Analysis and interpretation – The information will then undergo an analysis and interpretation.
- Report and presentation – The conclusions is summarized in a report from which the client or contractor can take action and make decisions (Andersson, et al. 2001).

The above process provides the method of this project. The seven steps of the market research process are similar of any scientific research, with the critical and questionable exception of the client or contractor usually searching for a specific conclusion rather than any conclusion. This report does not, however, solely figure as a tool of understanding the electricity feedback market and testing DEF on property owners, since it also involves other useful knowledge such as understanding energy use in buildings which should be of interest for any energy knowledge seeker. In accordance with the above presented, the character of this report should be considered as both non-scientific and scientific.

In cases where the investigator or the client has little knowledge of the investigation problem, the investigation, at least initially, has an explorative purpose. This means that the investigation is carried out like a voyage of discovery where you can not be entirely for sure tell where you are or where you are going. An exploratory investigation seldom gives clear answers, but has the aim of identifying and defining the problem area. If necessary, a more thorough and systematic study can be made later, but usually reliable and useful results obtained from an exploratory study are good enough, and it is not necessary or justifiable to carry out further investigations (Andersson, et al. 2001).

2.2 Data collection

A qualitative method aims at generating deeper understanding of the problem through different types of data collection (Andersen 1998). The data gathered is either from primary or secondary sources. Primary data is referred as original material and information collected by the researcher him- or herself, for example documentation from an interview. Secondary data is compiled by others for example information that can be found in a primary source, such as books and articles. When applying qualitative interviews focus should be on the interviewed person and how he or she responds to issues, rather than concentrate on the actual issues. Qualitative interviews are usually unstructured or semi-structured. The unstructured interview contains no prepared questions, and it is up to the interviewer to understand and follow up interesting tracks. A semi-structured interview is based on an interview guide containing a list of themes to be addressed during the interview. The themes may have several sub-issues but is primarily thought of helping out in case of the conversation have stalled and to cover the intended areas of the study (Bryman 2002).

This study investigates house-owners’ interest and need for getting improved technology metering systems, which is here considered to be of either unspoken or implicit meaning. For that reason, the customer survey has been performed as a qualitative investigation with semi-structured telephone interviews. Primary data collected for this study are the documentations from interviews and information from personal meetings with people possessing useful knowledge for the study. Secondary sources in this study are books, reports, regulation documents and web pages. To present examples of existing energy feedback systems on the market, some actual systems or services available for public use are briefly presented. Further processing is carried out to analyze uses for end consumers, presenting apparent technical strengths and weaknesses. The examples have been found using internet through search engines, ads, electronic papers and articles. The secondary data have been used to get an understanding of energy feedback, and its related market and product range which in turn has shaped the structure of the interviews conducted at the end of the project.

2.2.1 Literature review

Literature used for the study includes building physics, laws, regulations, investigations, and research reports. The findings of the literature are mainly used in Chapter 3, 4 and 5. In building physics, the book *Byggnaden som system* by Enno Abel and Arne Elmroth has been important in the process of achieving the underlying perspective. This knowledge has served to assist when the customer survey was prepared and performed. Without technical knowledge about energy use in buildings, it would be a difficult task asking questions about it and collecting answers given by property owners. This reference has been used specifically in Chapter 3, but as already explained, also provided a base for the study as a whole.

In the aim of investigating existing meter equipment including the advanced meter rollout, the two reports by ESMA have been particularly useful. The reports cover the rollout of advanced meter readers in Europe, with highly up-to-date information also discussing difficulties and lessons learned during the progress. Other reports and books on energy technology and human behavior have been used for the study. The research by Darby and Fischer has been useful in getting a perspective on energy feedback. Both researchers have produced plenty of reports on the subject. Darby's research has provided the structure of presentation on different types of energy feedback used in this study. The findings of these reports are mainly used in Chapter 5.

2.2.2 Interviews

Initially, an interview was performed with several workers at the company Energikontroll AB, daily working with energy technology issues and over large parts of Sweden. Much of their work relates to energy certification and energy inspections. The interview was of a qualitative nature with the unstructured method, and conducted primarily for broadening purpose and to get a briefing on how the energy certification of houses is carried out. The interview took place at Energikontroll in Uppsala.

For the customer survey, semi-structured interviews with property owners have been conducted over telephone. A structure has been followed with the prepared template, including pre-defined answers for some of the questions. The template is given in Appendix C, only in Swedish. With the semi-structure, most of the answers have matched the pre-defined answers and set of response alternatives. When needed, follow-up questions have been used for clarifying vague answers. An interview had a target time of 10 minutes. The procedure of interviews used for the customer survey, are further explained with the results in the beginning of chapter six.

Obtaining a random selection is critical to a study with any kind of generalizing motive. Although the customer survey included in this study has no specific intention of drawing comprehensive conclusions, for example for an entire population, it still has the aim of drawing useful conclusions of the selected type of property owners. At the same time, the intentional selection based on given criteria has been needed for the study. The result was that three, out of the total of twenty-one, interview subjects initially was given with contact information by the supervisors of the project. The three initial subjects are acquaintances or associates of the supervisors, but had no connection to the researcher. When the initial interviews had been performed, they were asked to recommend another similar subject who they thought had no objection to answering such questions as he had just responded to. And so in that way could the recruitment process for the interviews continue, without any problem reaching out to new subjects. At first, a number of 10 was the goal for getting subjects included for the customer survey. This was later changed as the process of reaching more suitable property owners became rather easy.

Contacts have also been made with several of the major DSO’s in Sweden including Vattenfall, Fortum, E.ON., and Mälarenergi, where some information has been gathered through customer service. In cases where the customer service was not able to answer specific technical questions, a network engineer could generally give the answer.

2.3 Selection of property owners

There are many property owners who could be potential users of disaggregated energy feedback. For that reason, a selection of property owners has been made in consultation with the supervisors for the project. The selection is somewhat based on own expectations but to some extent also throughout the results of statistics, other similar studies and useful surveys. The selection of property owners was based on the following criteria:

- Property owners should be randomly selected house-owners
- Electrically heated houses are main subjects, but other heating systems may occur
- House-owners who are landlords, with inherent tenants, should be involved if possible
- Variations of household members should occur, as well as level of electricity consumption and energy use
- Variation in age of house-owners should be sufficient

In line with the method for reaching out to house-owners as described above in section 2.2.2, a number of twenty house-owners have been interviewed. The house-owners consist of two owners of a terraced house, sixteen regular house-owners, and two house-owners with tenants. In addition, one tenant has been interviewed since the possibility was given, and this was seen as an opportunity of getting an idea of a tenant’s situation and thoughts regarding electricity consumption and energy use. This was thought of as bringing further understanding to the study, contributing to the interviews made with landlords.

2.4 Criticism of the sources

The chosen examples to present actual energy feedback systems are a limited subset of a wide range of systems available today. More and more products with similar characteristics are showing up continuously. Therefore, it is possible that products and participants who could have acted as good examples have been missed out during the time of writing. The presented examples are, however, of good illustrative character, and several of them can be considered commercial successes in their respective country of origin. Some of the sources used are to be considered of biased or non-controlled character, but they are favorably used only with descriptive purposes.

The presence of random selection can certainly be better than what has been done in this customer survey, which had been even more critical had it been a quantitative large-scale survey. The recruiting method was made in accordance with the supervisors to the project, and was regarded as a reasonable and experimental choice of approach.

3. Energy use in buildings

This chapter intends to give a basic perspective on energy use in buildings. It deals with fundamental building physics, accompanied by actual statistics of energy and electricity use in the residential sector in Sweden. Lastly, some examples of energy efficient measures are given.

Energy use in houses
According to Abel and Elmroth, the existing buildings are the most important of processing from an energy perspective. While it is very important that new buildings are designed so that their energy use is low and the indoor climate is good, it is still existing houses that are most important since the annual new construction represents less than 1 percent of the existing building stock in Sweden (Abel and Elmroth 2006). The number of houses was by 2007 approximately 1.74 million (Swedish Energy Agency & Statistics Sweden 2009).

The situation for the existing building stock speaks for itself, with 90 percent of the buildings that we will use in 50 years are already built today. It is therefore important to seize every opportunity to improve energy efficiency in existing buildings. Reducing energy demand can be achieved through relatively simple measures, is a question of measures that should be included in the natural maintenance, continuously carried out anyway (Abel and Elmroth 2006). From a life cycle perspective, 15 percent of energy is used for construction of the house, 85 percent for using it during its usage time and less than 1 percent to demolish it when the usage time ends (Persson 2002). Energy use during the life-cycle of a building is the most important factor to take into account for the life cycle environmental impacts of buildings.

3.1 The climate envelope

In any building, energy is being used for the energy-consuming activities that occur within the building, and for maintaining a desired indoor climate. A house indoor climate is determined by:

- The outdoor climate
- The activity in the building
- The building's thermal technical characteristics
- The climate controlling technical installations (Abel and Elmroth 2006)

The climate controlling installations compensate for when the interaction between building, activity and outdoor climate not in itself can provide the thermal climate and air quality required by people or indoor activities (Abel and Elmroth 2006).

The climate envelope[1] consists of the components of a building forming the border to outdoor air. Exterior walls, windows, doors and roofs are included in the climate envelope. Floor adjacent to the ground, as well as other building components adjacent to unheated spaces are also included. Based on the given climate, the quality of the climate envelope

[1] Own translation of the concept which is described in the reference of literature.

determines the size of transmission losses for the building. Heat transfer through the climate envelope has two main sources. It is partly the result of heat transmission through walls, roofs, floors, windows and doors, and partly by the heat transfer through ventilation with air escaping through leaks in the climate envelope (Abel and Elmroth 2006). Transmission losses may vary from house to house, but an illustration in *Figure 3.1* gives typical figures on heat losses through the climate envelope.

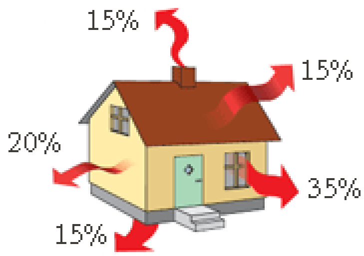

Figure 3.1 – Typical heat losses of a house (Municipality of Sundsvall 2009)

3.2 Heating in residential buildings

During the oil crisis of the 1970s the desire in Sweden was to convert the use of heating source from oil to electricity. Today the aim is to move away from oil heating and direct electrical heating. Heating and hot water account for 61 percent of the energy use in the residential and service sector in Sweden. Of the total amount of warming in 2007 for this sector, houses account for 41 percent, apartment buildings for 32 percent, and 27 percent was accounted for by office and commercial premises and public buildings (Swedish Energy Agency 2009).

Three ways of obtaining heat by converting electrical energy into heat is through the following main types.

- *Direct electrical* – Conversion of electricity to heat in electric radiators. 1 kWh of electricity provides 1 kWh of heat.
- *Electric boiler* – Conversion of electricity to heat in an electric boiler. 1 kWh of electricity provides 1 kWh of heat.
- *Heat pump* – Conversion of electricity through a work process. 1 kWh of electricity gives about 3 kWh of heat (Abel and Elmroth 2006).

The most common way to heat houses in Sweden is to use electric heating. This was done in about one third of the houses in 2007. Of these, about half of them have direct electric heating installed, and the rest is by water based electric heating. The reason why electric heating is used in so many houses can be explained by that it is inexpensive to install and easy to handle. The use of electric heating increased sharply among single-family houses from 1970 to mid-1980s during the transition from oil. In addition to only using electric heating, it is also common with a combination of electricity with an additional heating system. Bio fuels and electricity was the most frequently used combination with 23 percent of the houses in 2007. The use of heat pumps has increased a lot in recent years and in

2007, a heat pump was installed in 37 percent of the houses (Swedish Energy Agency 2009).

3.3 Electricity consumption in residential buildings

In addition to electricity optionally used for heating and hot water in houses, electricity is included in building-specific electricity and household-specific electricity. The building electricity is required to run various installations in a building, such as fans for ventilation and pumps for circulation of water. The household electricity is electricity used for lighting, appliances and other electrical equipment in a dwelling (Abel and Elmroth 2006). A typical existing house has more energy use than a newly built house.

Examples of energy use, including heating, hot water, building electricity and household electricity, for both existing and new residential buildings in comparison are given below in *Table 3.1*.

Existing house	kWh/m2 and year	Percentages	**Newly built house**	kWh/m2 and year	Percentages
Heating	150	71 %	Heating	40	34 %
Hot water	25	12 %	Hot water	25	22 %
Building electricity	10	5 %	Building electricity	25	22 %
Household electricity	25	12 %	Household electricity	25	22 %
Total	**210**	**100 %**	**Total**	**115**	**100 %**

Table 3.1 – Comparison on energy use of a typical existing house and a newly built house in Sweden (Abel and Elmroth 2006)

For the year of 2007, an average of 17 200 kWh of electricity was used in houses heated solely by direct electric heating, and 20 300 kWh of electricity in houses that are heated with water based electric heating (Swedish Energy Agency & Statistics Sweden 2009). The estimated annual consumption in Sweden of household electricity was to an average of 6 000 kWh per house, while households in apartment buildings is supposed to annually use 40 kWh per m^2 (for example an apartment with 70 m^2 will then use 2800 kWh). During the period of 2005-2008 a field study was performed measuring 400 households to examine how the household electricity is allocated to different uses. Analyzes are still ongoing, but the preliminary results suggest that there are large differences of the overall electricity consumption among different households. The annual usage can vary between 2 000 and 7 000 kWh for a house, and between 1 000 and 5 000 kWh for an apartment. In the case of different uses, the result shows that when taken an average over the whole year, lighting is the single largest item. Food storage (such as refrigerator and freezer) is the second largest item, and entertainment electronics (such as TV and computer) is the third largest item (Swedish Energy Agency 2009). Despite different calculation methods, the trend is clear; the household electricity consumption in houses, shown in *Figure 3.2*, has increased by 57 percent over the period 1970 to 2007.

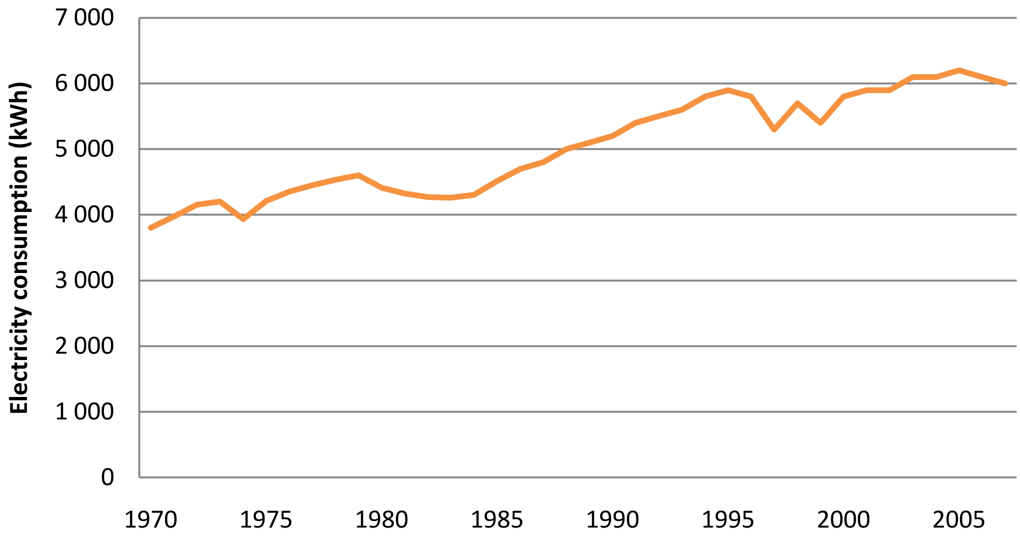

Figure 3.2 – Household electricity use in Swedish houses 1970 – 2007 (Swedish Energy Agency & Statistics Sweden 2009)

The use of electricity for devices is affected by two opposing trends. Through technology development the efficiency is improved of new devices replacing old and energy-consuming products. At the same time many new devices are equipped with more functions, using more energy. Moreover, the decrease in energy use is offset by the increasing number of households and that many households have more and more electrical appliances (Swedish Energy Agency 2009).

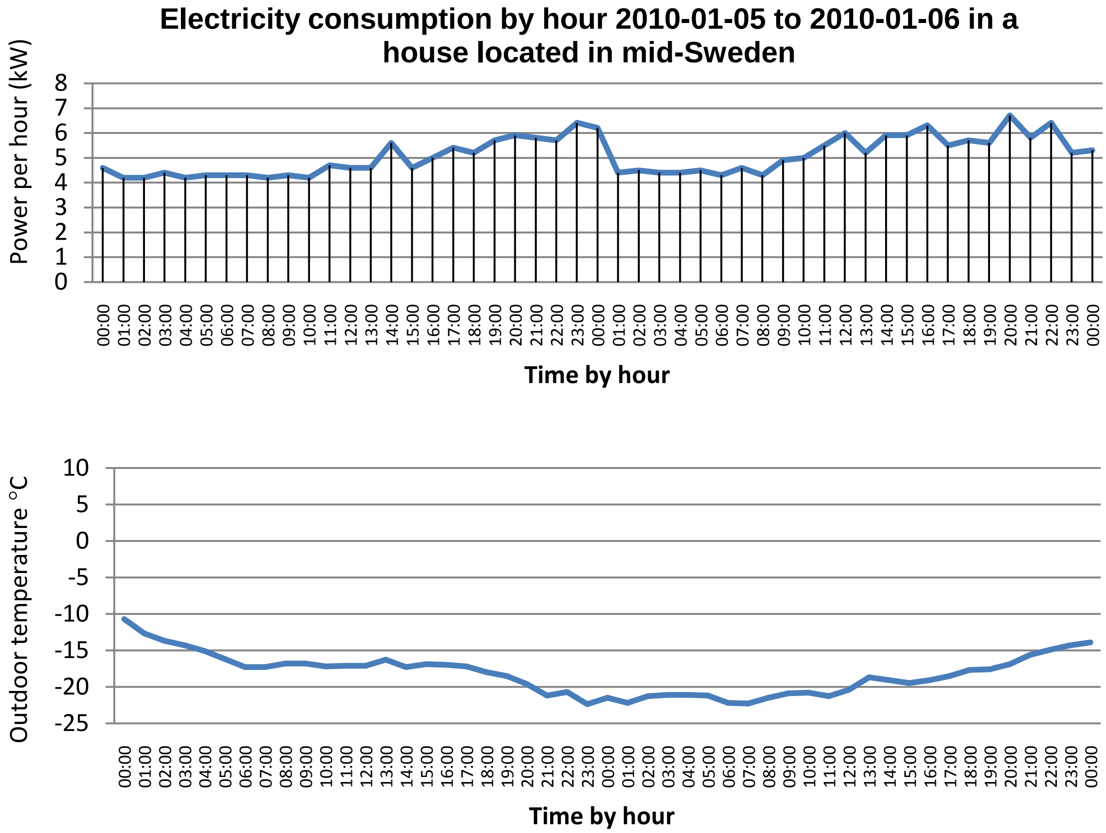

Figure 3.3 – Hourly data on the electricity consumption in a house located in mid-Sweden

Figure 3.3 shows measured hourly data, kindly supplied by one of the house-owners who took part in the customer survey for the study, for the two day period of 2010-01-05 and 2010-01-06, which had cold outdoor temperatures. Peaks suggest that the activity-related electricity consumption per hour during these two days was up to nearly 3 kWh.

Seen on the total electricity consumption in Sweden, an approximate annual amount of 16 000 kWh of electricity is used per inhabitant. Only Iceland, Norway, Canada and Finland have higher electricity consumption per capita. In the US, electricity consumption per capita is 10 percent less compared to Sweden, and in the EU15[2] electricity consumption per capita is on average 54 percent less than in Sweden. The high electricity consumption in Sweden could be explained by the existence of a large proportion of electricity-intensive industries, a cold climate, historically low electricity prices, and a high proportion of electric heating (Swedish Energy Agency 2009).

3.4 Energy efficient measures

There are many ways to mitigate high energy use in a house. They can be construction-related measures, but also activity-related. The measure is only energy efficient depending on two aspects. Firstly, it must not impair the usefulness of the house and particularly the

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[2] The EU15 comprises the following 15 countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and United Kingdom.

indoor climate. Secondly, the actual energy savings must be reasonable in relation to cost. The latter gives a hint of the important concept of cost-effective measures. A cost-effective measure is an energy efficient measure, which despite the investment and maintenance cost on behalf of the savings in energy costs will result in lower costs than if it would not have been done (Abel and Elmroth 2006). Potential energy efficient measures vary from house to house, but may very well include the following.

- Reduce heat losses through the climate envelope – Primarily check insulating properties of windows and attic, but also of the walls and doors that may be appropriate in older houses.

- Replacing the heating system – In many houses, the compensation of an oil boiler or electric boiler with any other heat supply is the most obvious major energy measure. The same applies to direct electric heated homes, but they are more difficult to handle because a conversion also requires the installation of a distribution system for the heat. With closely reviewing and thorough economic calculations made, the best option for the house need can be chosen.

- Adjustment of pump operation – Circulation pumps in radiator systems have very little power requirements, typically 50-90 watts in single-family houses. If they are in operation throughout the year though, the resulting energy required is 400-700 kWh per year. The pumps usually have a very poor efficiency, and less than 10 percent are not uncommon. The pumps should be stopped during the summer months, where the function should be checked again when restarted. Replacement of old pumps to those with better efficiency can be economically justified (Abel and Elmroth 2006).

Figure 3.4 shows measured monthly data, also supplied by a house-owner, on the electricity consumption for the period before and after a bedrock heat pump was installed for heating which in the past was done by an electric boiler.

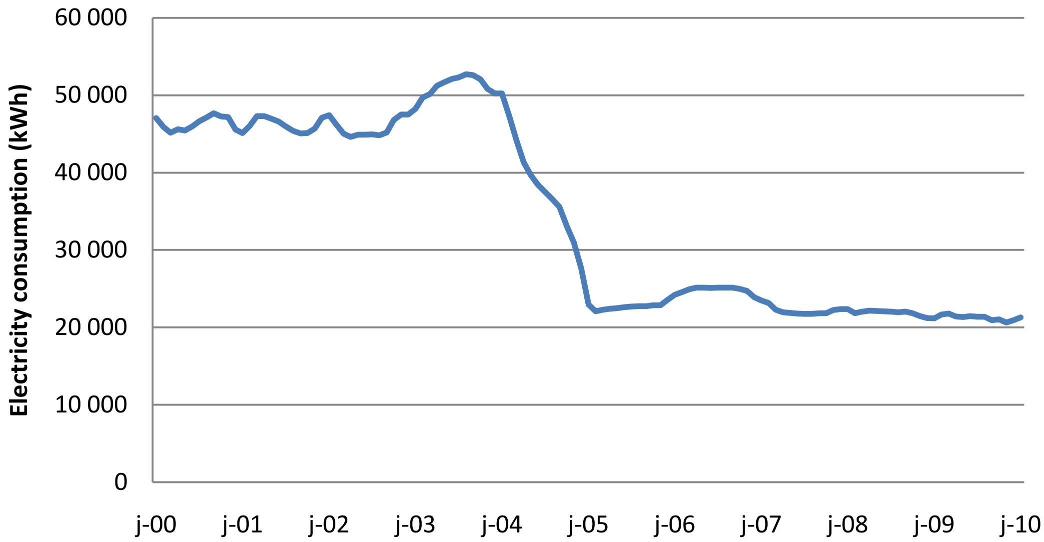

Figure 3.4 – Example of an energy efficient measure on installing a bedrock heat pump for a house located in mid-Sweden

There are many potential activity-related measures creating significant less amounts of energy use. These are the measures related to the consumer behavior. The unit kWh, of course, simply consists of both power and time unit. To replace a broken light bulb with a more energy efficient bulb provides savings, but the number of hours that lights are used must also be taken into account. Lowering the temperature of 1 degree Celsius, will in many houses result in 5 percent less use of the overall energy use and cost.

The final words of this background and perspective-giving chapter would be that a house-owner should have a greater influence over the energy use than an apartment owner has. This goes both in terms of energy used and in the potential of reducing the use of energy. While the individual apartment owner can most easily affect only the consumption of household electricity, any house-owner in terms of energy use should be well placed of affecting more than that.

4. The energy and electricity distribution market

This section presents relevant and up to date information on the present status for house-owners and their electricity and energy use. The chapter includes background information and a description of the electricity billing system in Sweden. It also presents various directives on different levels that influence and drive the development of energy use in households. A brief presentation of legislation and directives on electricity metering is given.

4.1 Electricity price market

The shift from national or regional monopolies to international, competitive markets has lead to major changes. Within Europe and the Nordic countries electricity users can choose their supplier. All Nordic countries, except for Iceland are participating in the Nordic electricity exchange called Nord Pool. The Nordic electricity market is increasingly integrated also with markets south of the Baltic Sea, mainly Germany and Poland. Trading of electricity is already carried out with Finland, Russia and the Baltic. The price of electricity in the Nordic region is mainly influenced by water inflow in Sweden and Norway, operational status of nuclear power plants in Sweden and Finland, the international price situation of various fuels, and the existing means of control (Swedish Energy Agency 2009).

Within the European Union (EU) there is a large effort to deregulate the electricity market. The directive 96/92/EC of December 1996 included common rules for the internal market in electricity with deregulation, and a political agreement on completing the process was attained in November 2002. The objective was to make all non households eligible by 1st of July 2004 and all electricity customers by 1st of July 2007, with assorted exceptions granted to certain countries (EUROSTAT 2007).

4.1.1 The electricity price system in Sweden

Sweden has to date 195 registered electric network companies (Svenska Kraftnät 2009), which include the three major operators E.ON Elnät Sverige AB, Fortum Distribution AB and Vattenfall Eldistribution AB. Competition has been applied for production and trade of electricity since it was introduced due to a reform of the electricity market on 1 January 1996. The companies that are responsible for the transmission of electricity have local or regional monopolies. They must be legally separated from companies producing, trading and selling electricity. When introduced, all consumers were eligible in the new market if the consumption of electricity was measured by the hour which was later abolished in November 1999. All consumers have since then had the possibility to change electricity supplier without incurring costs. The costs of the transmission of electricity are supervised by the Energy Markets Inspectorate. In the spring of 2002 the Swedish Parliament decided on certain changes to the electricity act, which included the change of the criteria for reasonable network charge. According to the new regulation, reasonable assessment should be based on the performance of the network companies (EUROSTAT 2007).

The total price of electricity for households consists of the following:

- The price of electrical energy (energy charge)

- The price of network charges (transmission charge)
- Taxes (energy tax and VAT)
- Price of electricity certificates

Both the energy charge and the transmission charge can be divided into a fixed part and a variable part for the consumers, related to the amount of electricity used. The distribution of the energy charge is presented in *Figure 4.1*.

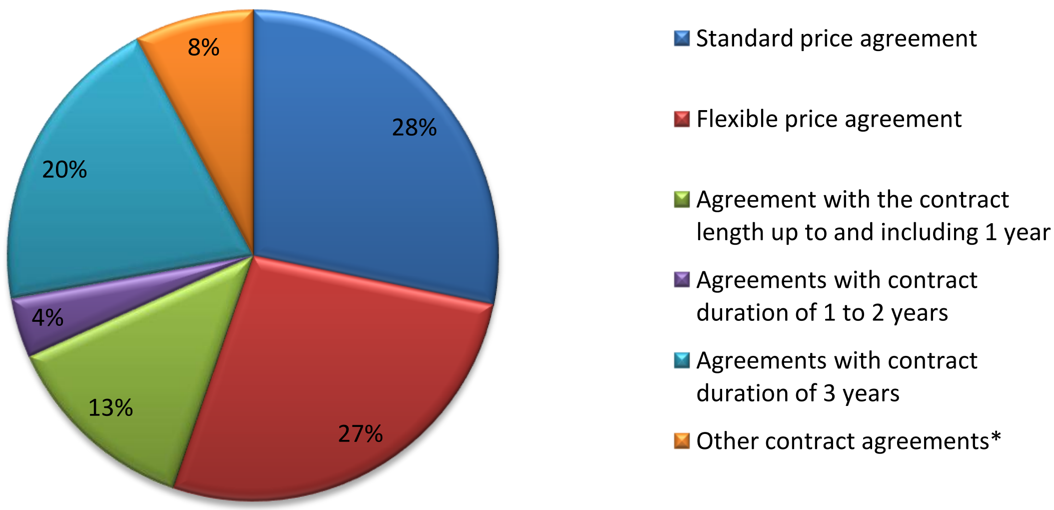

Figure 4.1 – Distribution of all Swedish customers for different types of agreements, as of June 2009 (Statistics Sweden, Swedish Energy Agency 2009)
**other contract agreements are often combined contracts or long contracts*

Among all Swedish customers the recent development show as of June 2009 a significant increase (from 19 percent to 27 percent) in the proportion of flexible price agreements in comparison with previous year, and a further reduction (from 36 percent to 28 percent) in the proportion of standard price agreement, or “until-further-price-agreement” (Statistics Sweden, Swedish Energy Agency 2009). Flexible price agreements may be thought of as more suited for electricity consumers who are active on the electricity market. The flexible price agreement is connected to the monthly average spot price on the Nordic power exchange Nord Pool. The spot price is set once per hour, based on supply and demand (Nord Pool 2010). According to Vattenfall, mild and wet weather usually leads to lower prices, while cold and dry weather leads to higher prices. Examples of other factors affecting the stock price are the economic situation and the price of coal, oil and emissions (Vattenfall AB 2010). Notably, Vattenfall is the only major company in Sweden offering time-of-day tariffs, and is available for customers with an annual consumption of more than 10 000 kWh, including the high price period from November to March, Monday to Friday between 06:00 and 22:00, and the low price period all other times. (Vattenfall AB 2010)

The price of electricity is set by the suppliers without government regulation, and since it is an open market the price differs between different suppliers. The total price of electricity can usually vary between different consumer categories and between urban and rural areas, due to variations in distribution costs, taxation, and subsidies, but also due to the structure of the electricity market (EUROSTAT 2007). Although energy charges dropped during the period 2008 to 2009, especially the type of flexible price agreement, the average total electricity costs for household customers still increased slightly (Statistics Sweden, Swedish Energy Agency 2009). This is presented in *Figure 4.2*, with regular house-owners unlikely to belong to the group of customers with an energy consumption of below 1 000 kWh.

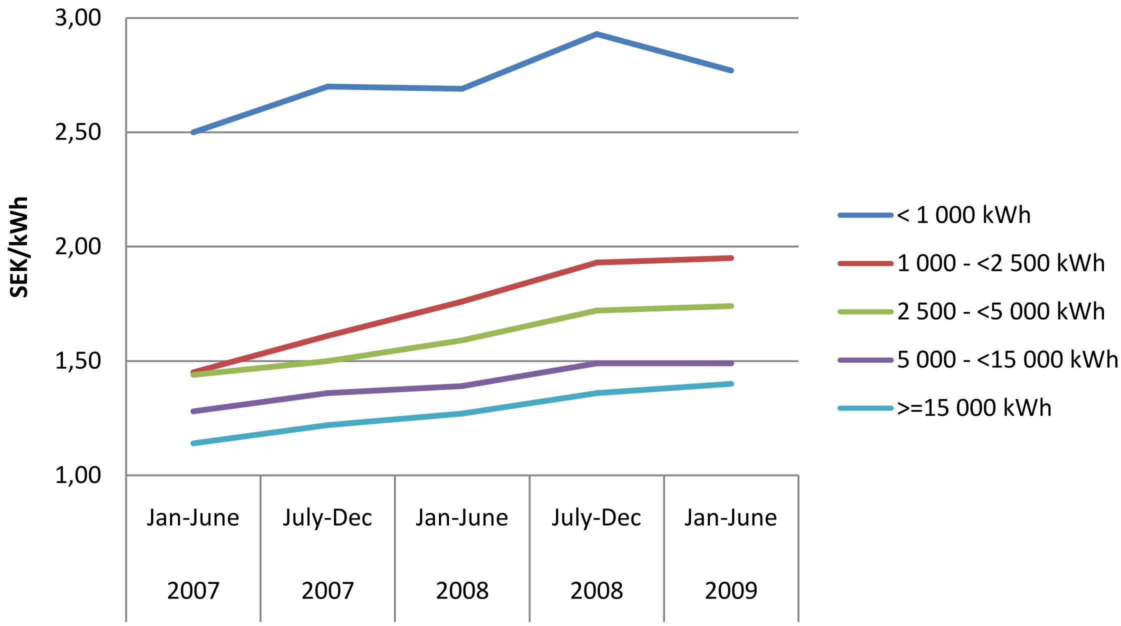

Figure 4.2 – Recent total price of electricity for Swedish household customers, based on what groups of customers pay on average half a year (Statistics Sweden, Swedish Energy Agency 2009)*
**including energy charge, transmission charge, energy tax and VAT, and electricity certificate*

For consumers, the fixed price and the price of electricity per kWh usually depend on the size of meter fuse installed in the house, the consumption pattern and the amount of electricity used in one year. At present, a little less than half of the price may be affected by changing supplier in the competitive part of the electricity market. The price of electricity, or energy charge, is therefore the competitive element. To subscribe to the right size of electrical power is also a way to avoid unnecessarily high fixed charges for electricity customers. In 2006, households paid an energy tax on electricity consumption of either 0.186 SEK/kWh or 0.282 SEK/kWh, depending on location and municipality. For an average consumer with an electrically heated house, the composition of the price of electricity, as of 1 January 2009, was about 48 percent electrical energy price, 15 percent transmission and 37 percent energy tax and VAT. The composition for the average consumer is presented in *Figure 4.3*.

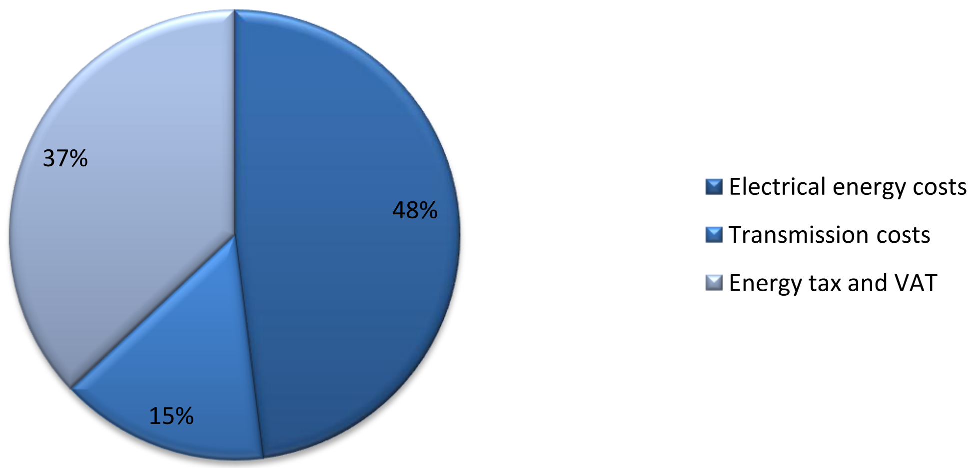

Figure 4.3 – Composition of the electricity costs for Swedish households, as of 1 January 2006, average consumer in an electrically heated house. (Swedish Energy Agency 2009)

A good deal of the debate on the upcoming movement in Sweden towards lower energy use in households, and lower energy bills, is the consequence of different directives and actions from the EU. The purpose of many specified targets and directives is to help the EU to meet its commitments under the Kyoto Protocol, which is an agreement between countries to jointly tackle the global threat of climate change (Swedish Energy Agency 2008).

4.2 EU Energy end-use efficiency directive

In an article, participating in The European Council for an Energy Efficient Economy 2009 Summer Study, the researcher Darby deals with recent energy metering and billing issues. The first-ever European conference on metering, billing and customer relations was held in 1998, which only attracted about 100 participants. In 2008 the attendance had risen to more than 2 700. This development points out that metering and billing have become hot topics. Representatives and policy makers try to understand what is technically possible and who might make benefits or lose from new developments. Manufacturers and software designers are now marketing new developed products with billions of Euros worth of investments at stake (Darby 2009). In April 2006 the European Parliament and Council of the European Union presented the EU Energy end-use efficiency and energy service directive. Darby stresses the articles 1, 11 and 13 of most relevance to energy feedback and metering (Darby 2009). Article 13 of the Directive gives the requirements of Member States to ensure that energy consumers have frequent and informative billing. It also gives requirements on improving meters to reflect consumption accurately and provide information on time of use. How countries decide in drafting laws and regulations to comply with the Directive is up to each Member State. Darby brings up important details in the prescribed requirements of the Directive and Article 13. The goal is to make better energy feedback information available to energy users, rather than setting framework for any specific new technology doing so. A selection of the most relevant extracts of The Directive is presented in *Table 4.1*.

Recently, the European regulatory platform Citizens' Energy Forum presented objectives in line with the Directive and Article 13.

… Furthermore, consumers must be properly informed of actual electricity consumption and costs frequently enough to enable them to regulate their own electricity consumption. Smart Metering, in electricity at least 80 percent of those consumers which have been assessed positively has to be equipped with intelligent metering systems by 2020. In the case no economic assessment of the long-term costs and benefits is made, at least 80 percent of all consumers have to be equipped with intelligent metering systems by 2020.

Citizens' Energy Forum, Brussels 30 September 2009

The Citizens' Energy Forum was launched by the European Commission in 2008, and is intended to discuss and promote creation of competitive, energy efficient retail markets and protection of consumer interests (European Comission 2009). The process of introducing smart metering systems in Europe is yet however far from apparent and precise, and more information and recommendations from the European Commission working groups are likely to come. Despite this, a growing number of European companies, regulators and governments have more or less completed the implementation (for example Sweden, Italy and Finland), while other countries are in the investigating stage. One problem is also that there have been plenty of meters with broad variations of being "smart" meters. More on smart metering systems is presented in Chapter 5.

The EU Energy End-use efficiency and energy services directive (2006)

Preamble
In defining energy efficiency improvement measures, account should be taken of efficiency gains obtained through the widespread use of cost-effective … innovations, for example electronic metering ...

To enable final consumers to make better-informed decisions ... they should be provided with a reasonable amount of information ... consumers should be actively encouraged to check their own meter readings regularly.

Article 1
The purpose of this Directive is to enhance the cost-effective improvement of energy end-use efficiency in the Member States by:

(a) Providing the necessary indicative targets as well as mechanisms, incentives and institutional, financial and legal frameworks to remove existing market barriers and imperfections that impede the efficient end use of energy;

(b) Creating the conditions for the development and promotion of a market for energy services and for the delivery of other energy efficiency improvement measures to final consumers.

Article 11
... Member States may establish a fund ... to subsidize the delivery of energy efficiency improvement programs and ... measures ... These measures shall include the promotion of energy auditing ... and, where appropriate, improved metering and informative billing.

Article 13
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 ... are provided with competitively priced individual meters that accurately reflect actual energy consumption and that provide information on actual time of use.

... Billing on the basis of actual consumption shall be performed frequently enough to enable customers to regulate their own energy consumption.

Member States shall ensure that, where appropriate, the following information is made available to final customers in clear and understandable terms ... in or with their bills ... :

(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 graphical form;

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

Table 4.1 – A selection of the EU Energy End-use and energy services directive (Darby, 2009, p.454, CEC, 2006, p.64-72)

The objective of 20 percent reduced energy use by 2020 in Sweden

According to a suggestion by the Swedish Government, the Parliament did in June 2006 present the objective of lowering the energy use by 20 percent per heated space unit until year 2020 in residential and tertiary sectors, compared to the energy use as it was 1995. Furthermore, the target is to reach the 50 percent level by 2050. Also, by 2020 the dependence on fossil fuels for energy use in the building sector should be broken, while the share of renewable energy continuously increases. According to the Environmental Objectives

Secretariat the trend is now in the right direction, since heating is becoming more energy efficient, renewable energy increases and the proportion of fossil fuels is decreasing. However, it is uncertain whether or not the specified target levels of the objective can be reached in time without further action. A general energy efficiency priority to be given is encouraged (The Environmental Objectives Secretariat 2009).

4.3 The electricity measurement market

As already mentioned, the European Union has decided that all member states are required to adjust to the smart metering system by 2020. The decision should result in all involved households having some kind of smart meter installed by then.

To date some countries have moved towards deregulation of the electricity market more than others, with deregulation of the electricity measurement market. This has been done in the UK, Germany and within several states in the US (Meterpedia 2009).

4.3.1 The electricity measurement market in Sweden

As mentioned in the beginning of the chapter, Swedish network companies have local or regional monopolies, which also include the energy measurement market. This means that the network companies own the meters. A house-owner usually owns the cabinet, plate and wiring for the installed electricity meter, but the meter itself is owned by the network company. Choosing among various network companies is not possible. As an electricity consumer there is simply no other choice but to sign an agreement with the network company that is available at the location of your house.

There are also established regulations on the measurement, collection and reporting of metrics and how billing should be done for DSO's activities. A variety of regulations have been prepared by industry organization Swedenergy by agreement with the Swedish Consumer Agency (Swedish Consumer Agency 2008). Some of these regulations, of relevance for this study, are mentioned below.

Since 1st of July 2009, all electricity meters in Sweden must be read at least once a month, for charging of actual consumption rather than estimating the consumption based on annual readings. This is due to the Regulation (2006:1590) amending the Regulation (1999:716) on measurement, calculation and reporting of transmitted electricity (SFS 2006:1590). The regulation itself set no technical requirements for measurement systems, including only the functional requirement for meters to be read once a month. The framework has in practice resulted in the electricity companies have chosen to install electricity meters that can be remotely read (Energy Markets Inspectorate 2009). Some of the expected advantages and consequences, according to the Swedish Energy Agency and Swedenergy, of introducing monthly readings were that:

- Electricity users would be given understandable and informative invoices, which would, among other things, encourage electronic conservation. Also switching electricity supplier would become easier, and the routines when moving to a different location would be simplified.

- Electricity trading companies would lower the administrative costs of managing the customers.
- The electricity network companies would have huge costs associated with the investment itself, but at the same time benefit by streamlining their operations (Swedish Energy Agency 2002) (Swedenergy 2009).

As a result, the Automated Meter Reading (AMR) has rolled out in Sweden between 2006 and 2009. Swedish Board for Accreditation and Conformity Assessment (SWEDAC) is the regulator for AMR systems in Sweden, and has provided rules for the verification of measurement equipment for domestic customers. In the regulation it is determined that an electricity meter should be checked through periodic inspections to fulfill established requirements. The rules apply to all DSO's in the country (SWEDAC 2009). In practice, a certain number of meters from a production series will undergo the verification after three years of use. The selection of these meters is made by SP Technical Research Institute of Sweden (SP), which is in control of the process. If the selection passes the test, all meters of the production series will be approved. The next inspection is conducted after another three years of time, and so the process continues. If the selection fails during verification, all meters of the production series must be replaced.

Discussion of deregulating the market for electricity measurement

At present, there is a growing opinion in Sweden for a deregulation of the market of electricity measurement. According to the Swedish Academy IVA, deregulation is critical for improving opportunities of reducing energy use in households in Sweden. The Academy argues that since the meters are owned by energy companies (Vattenfall, E.ON and Fortum, for example, are operating as both energy companies and network companies), their incentives to develop services that reduce energy use are limited. IVA also proposes that it should be required that the electricity meter provides information for use both in real time (Power) and per hour (Energy). The information should be used partly by electricity companies in order to optimize production, and partly by the user to select the time of day you want to start appliances with high-energy use in order to minimize environmental impact and price (Kungliga Ingenjörsvetenskapsakademien, IVA 2009).

To measure and visualize the energy is a very important tool. One choice is to deregulate the market for measurement and information and make it mandatory for energy companies to pay a certain fee for measurement values. It will lead to a market for the specific company that owns meters, and earn their money by selling their information. This leads to technology development, small businesses and energy efficiency.

IVA, 2009, p.23

The matter has also been raised in Swedish independent public service *Sveriges Radio*, where already familiar researcher Darby, on the other hand, believes that deregulation is not necessarily the best choice for Sweden. In giving her point of view she thinks that the development in the United Kingdom and Germany should be deterrent, with too many operators on the market which has created adverse conditions. But it is also mentioned that, according to Darby’s research, there are better saving potential with other studied solutions of energy feedback than using monthly reading and billing (Sveriges Radio 2009).

Another issue to address is that deregulation would perhaps require another operator involved, apart from the electricity supplier and the electricity network company. In case the metering information is targeted for the energy consumers, it may be appropriate having to deal with an additional operator when purchasing electricity. Of course it is also conceivable that such an operator could simply deliver metrics to for example the consumer's electric company, with the consequence of the electric company choosing what metrics to be offered to the customer. The subject on feedback and saving potential will be further addressed later during the report.

4.4 Means of control for energy efficiency

Several instruments to control the energy efficiency in Swedish buildings are available. Boverkets building regulations is one administrative instrument, and the Energy Performance Certification is another. There are also to date economic instruments in the form of tax credits for domestic work, investment support for conversion of heating systems, and investment in solar cells (Swedish Energy Agency 2009).

4.4.1 Tax credit for domestic work

The main purpose of the tax reduction is to reduce undeclared work and increase demand in the construction industry. The reason for the tax reduction also depends on the economic situation. Several energy saving measures are included; maintenance, repairs or refurbishments and expansions, are all deductible. The deduction was introduced on 8 December 2008 (Swedish Energy Agency 2009). The tax reduction is currently an important topic in political discussion if it should be kept or removed depending on which party that wins in the election in 2010.

4.4.2 Investment support for conversion of heating systems

The purpose of the economic support is to reduce oil dependency and a reduction in electricity consumption for heating purposes in the residential sector. Owners of properties with direct electric heating can be given assistance to switch to district heating, heat pump (lake, soil, or bedrock) or bio fuels. Support for conversion from direct electric heating was introduced 1st of January 2006, and the expiring date is set to 31st of December 2010. The support for replacing oil heating, however, has expired (Swedish Energy Agency 2009).

4.4.3 Energy Performance Certification

In June 2006 the Swedish parliament introduced a law on Energy Performance Certification of buildings in Sweden. It became operational in October the same year, and in March 2007 a regulation and general advice on Energy Performance Certification (EPC) of buildings was given by Boverket (The National Board of Housing, Building and Planning), on behalf of the Government. The purpose of the Act is to promote energy efficiency and a good indoor environment in buildings (The Swedish Government 2006). The Act includes both new and existing buildings. According to Boverket, the EPC has many advantages: In line with directives given by the European Commission, the EPC has the objective of reducing the use of energy and decreasing the emission of greenhouse gases; The EPC should also benefit any building owner since it must include cost-effective recommendations on measures to improve the energy performance of the building. Carrying out the suggested measures or not, however, is entirely the building owner's choice. Furthermore, the certification is carried out taking outdoor climatic and local conditions into consideration, and provides reference values which make it easier to compare the performance of Swedish buildings. As a final point, the certification has the aim of contributing to a sustainable society and counteracts global warming (Boverket 2009).

Owners of existing buildings, including owners of regular households, are to date however not liable to the availability of an EPC, except in the event of a sale of the building. This is, however, about to change since there has been a proposal from the EU, which is described further down. New buildings are to be certified two years from the day when the building was taken into use at the latest. The EPC is valid for 10 years. Residential blocks of flats, non-residential premises and special-purpose estates exceeding 1 000 square meter are required to always have a valid EPC that is no older than 10 years. There are exceptions, though, and some buildings are generally excluded from the EPC requirement. A few examples of such buildings are buildings mainly used for religious activities, industrial plants and workshops, holiday houses with not more than two dwellings, detached buildings with usable area of less than 50 square meters and buildings used for secret operations, for instance National Defense operations. Boverket has also informed step-by-step how the EPC is completed, presented in *Table 4.2*.

- You (the owner of the building, author's note) gather the basic documentation required and hand it to an energy expert at an accredited inspection body.
- In case there are details missing, the energy expert will go through the documentation and if needed see to it that a survey is performed on your building.
- If the expert's assessment says that the energy performance of the building is not satisfactory he or she will provide you with recommendations on measures to improve the energy performance. These recommendations will be cost efficient to your benefit, mainly as reduced energy costs.
- The energy expert registers the EPC in Boverket's database and provides you with a copy.
- The EPC summary must be displayed so all visitors and residents can acquaint themselves with the contents and results of the EPC.

Table 4.2 - Information on how the EPC is completed (Boverket, 2009)

According to Lars Blekastad, CEO of the company *Energikontroll AB i Sverige* performing EPC at a regular basis, the EPC carried out in houses does not usually have the same economic starting points as for large apartment buildings. According to Blekastad, how the EPC in houses is performed may vary. When Energikontroll performs EPC in houses, equipment and function is always checked, such as the function for a heat pump. The way, and quality, of carrying out the EPC in the approximately 80 000 houses sold each year may vary widely (Blekastad 2009).

The proposal for revised directive on EPC 2009

The proposal for a revised directive on EPC means that it would be included in all buildings undergoing major renovation. EU Member States should also develop plans for an introduction of low-energy and passive houses. The estimated energy savings resulting from the review is estimated to be between 5 and 6 percent of EU energy use (Swedish Energy Agency 2009).

5. Electricity feedback

This chapter gives the results from an investigation on techniques to provide energy feedback. Mainly, the techniques are intended for electricity metering but can in many cases also give water and heat measurement information. First, an orientation is given on the move from basic metering to smart metering, where the background and decision takings have already been presented in the previous chapter. This is followed by a brief presentation of several techniques of feedback. Lastly a more detailed description is presented of disaggregated electricity feedback and its applications for homeowners.

5.1 Standard metering

As described in the previous chapter and Section 4.3, it is fair to say that the old standard electricity meters had the function of verifying the customer's bills in retrospective, while the new meters are intended to make the bills based on actual consumption and also to have more potential of producing additional data and services. One of the achievable additional services is increased electricity feedback, but there is yet great uncertainty of the qualities and the quantities of the feedback information to be produced.

5.1.1 Basic metering

An old standard gas or electricity meter without any separate direct display monitor can of course provide basic energy consumption feedback. The house-owner can monitor consumption from one meter reading to the next, and use the meter to check the accuracy of bills or statements. There is, however, no obligation to do either, and the meter is normally hidden out of sight, so using the standard meter as a feedback will require a level of commitment to reading the meter regularly. In addition to requiring a work input from home owners to obtain the feedback, the standard meter cannot determine when the consumption took place nor have any features for remote activation (Darby 2006).

Soon, however, old electricity meters will be more and more unusual as the AMR system rolls out in countries with the option of doing so. Many countries are in the process of planning the introduction and have dates set for implementation. There are also intense negotiations in areas such as the EU and the climate meetings, where the discussion right now is on what standards should be applied for the measurement technology.

5.1.2 Smart metering and smart grids

Smart metering has in recent years become a hot topic worldwide, especially in the US and within the EU. To get an understanding of what smart metering really is, it may be useful first to clarify what the idea of smart grid is. Smart grid is sometimes also called intelligent network. A problem with the terms is that they are both wide and ambiguous concepts, with several definitions depending on which of the possible services are included.

According to the Swedish National Electrical Safety Board the smart grid is really about a smart electricity system. Specifically, there are more and more electronics in our electric energy systems. Wind and solar energy, together with electric cars are examples where the electrical energy passes so-called power electronics. Another example is the transfer of information from electricity meters. With constant information about the price of electricity, for example electric cars can be recharged when electricity price is low. Similarly, electric cars could provide energy to the electricity system during times when electricity demand is high, for example in cold winter mornings. To make this possible, common standards covering everything from how devices communicate to overall electrical compatibility are a prerequisite, which is the reason why 19 technical committees world-wide are working with affecting the standards (The National Electrical Safety Board 2009). This can be summarized in the following description: The concept of smart grid is an electricity transmission and distribution network with a parallel communication network with digital meters, sensors and controllers that enable utilities to use renewable energy sources and reduce outages while empowering consumers with pricing choices, detailed information and automated appliances to save money, energy and carbon emissions (Meterpedia 2009).

After having clarified the function of smart grid (also called intelligent network), it is reasonable to assume that smart meters have their role within these networks. Such smart metering can therefore have the following features:

- Automatic processing, transfer, management and utilization of measured data
- Automatic management of meters
- Two-way data communication with meters
- Provide meaningful and timely consumption information to the relevant parties and their systems, including the energy consumer
- Support services that improve the energy efficiency of the energy consumption and the energy system (generation, transmission, distribution and especially end-use) (ESMA 2009)

Italy has installed over 30 million Automated Meter Management (AMM) meters transmitting meter data through power line communication (PLC) to a concentrator, and via the GSM network to the central system (Badano, et al. 2007).

In this system the following information is sent from the meter to the central system:

- Information on electricity quality, i.e. voltage variations, interruptions
- Consumption Information
- Operation and maintenance information (meter status)

And the below information is sent from the central system to the meter:

- Tariff and agreement information
- Control of power supply
- Software Upgrades
- Control signals for smart homes (Badano, et al. 2007)

The European Smart Metering Alliance[3] (ESMA) presents annual reports, with the beginning of 2008, which cover information on the implementation of smart metering

[3] ESMA is an alliance of companies and organizations for the advancement of smart metering in Europe, working to develop best practice in smart metering so as to deliver the best energy saving benefits. ESMA is

across Europe. The intention is to set out the current situation and to provide a rolling commentary on the progress of achieving energy savings and other social goods. According to ESMA, a significant number of EU member countries have taken major steps towards a full roll out of residential smart metering driven largely by Article 13 of the Energy Services Directive, the 3rd Energy Package and an environmental agenda. There are also developments of standards intended to make smart metering interoperable. These are being developed by the European Standards Organization (CEN/CENELEC/ETSI) in response to the European Commission Mandate M/441.The largest number of smart metering installations is currently being introduced in the US, although in Italy, Sweden and Finland smart meters are almost completely deployed. Most of the other projects are trials, or pilot projects, and many are assessing the impact of smart metering on consumer behaviors. These trials have yet to provide evidence needed to allow a conclusive view on the levels of energy savings, that smart metering can provide (ESMA 2009). However, according to Darby, even though there are many trials of both meter and in-home feedback displays under way, many results may never be published for reasons of commercial confidentiality (Darby 2009). A map of trials and smart meter roll outs has been created by Engage Consulting, located in Birmingham. Screenshots from the map created with Google maps, can be found in Appendix A, which gives a good picture of the worldwide rollout.

According to ESMA, there are a few main barriers preventing the spread of smart metering in EU and outside Europe. Those main barriers are legal, economic and technical, but there are also barriers related to awareness rising and customer reaction considered in the ESMA report. Except for the fact that there are still much uncertainty regarding the quantification of benefits due to lack of practical experience and historical data, also since there are so many parties involved, the benefits of the smart metering may accrue to other parties than the ones that bear the costs. Furthermore, in many EU countries there is significant reluctance from regulators to increase the tariffs to end users to pay for the roll out of smart metering, which is a very long and costly process. Still there are lack of interoperability between different smart meter systems since no open registered standard exists which properly scopes different functions of metering, communication, presentation and network. In addition, there is a lack of modularity and lack of flexibility of present mass production of smart meters. Special needs and functions regarding distributed generation, demand response, power quality, customer information, energy efficiency automation and other services can only be met with high extra costs (ESMA 2009). One should bear in mind that these special needs and functions are often highlighted when smart metering is mentioned.

Smart homes with the example of Tempo, in France

By introducing yet another ambiguous concept with the example of the Italian smart metering system, *smart homes*, does not make things easier. It usually involves home automation of different household appliances, possibly with lighting, heat, ventilation and air conditioning control. It can also involve security and surveillance systems. Smart home can simply mean many things for a homeowner. In this study, they should be seen as the result of the benefits, which smart metering and smart grid ultimately can bring to ordinary homeowners. To a certain limit, the purpose of this thesis is to investigate if Swedish

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formed by interested organizations with partial funding from the European Union's Intelligent Energy for Europe Programme. More information can be found on the website: http://www.esma-home.eu homeowners are interested in what the smart home can bring, but with less specific interest of automation and more interest in energy feedback for the homeowners.

In France, the roll out of smart meters is still under decision, but is expected to be carried out and completed between 2010 and 2020 (ESMA 2009), so today there are yet no AMM systems in households. State-owned electricity company Électricité de France (EDF), with a very strong position, has, however, had the ambition to offer households variable prices for some time which is what distinguishes France in introducing Demand Side Management (DSM) for its household customers. To determine what framework should apply to the AMM in the future, the French Energy Agency ordered techno-economic studies of what happens in the rest of the world with analysis of what level of functionality that will be most suitable for France when all electricity meters have been phased out. This was done expecting a future-electricity market where reduction of carbon emissions becomes more important, oil becomes more expensive, with major investments in the electricity grids, and where reductions in peak load becomes increasingly urgent. The studies have found that it is the most advanced AMM systems which will benefit the consumers most. For the DSOs and electricity suppliers, the advantages of the AMM systems are not equally significant as for the consumers. For DSOs, the system with middle-functionality is the best from an economic point of view, despite additional functionality was at low cost (costs differed only 7 percent between three studied scenarios containing systems with varying degrees of functionality). From the consumer perspective, more information regarding consumption, time-differentiated tariffs, and the ability to automatically control electrical appliances in the home depending on price or power situation, are all considered as mandatory functions (Badano, et al. 2007).

Even without AMM, the French EDF has already since 1996 provided household customers, equipped with digital meters, with the tariff called *Tempo*. With Tempo, the year is divided into 22 red days when the kWh price is very high, 43 white days when the kWh price is quite high, and the remaining 300 blue days when the price is the cheapest. Electricity prices are also cheaper between 22:00 to 06:00 regardless of the color of the day, making a total of six different levels of the electricity price. The customer receives preliminary data of next day's color from EDF by 16.30. The final decision of a red, white or blue day is taken and delivered to the customer at 20:00. Color information is sent using PLC to a device connected to any wall socket within the house, handed out with the signing of the agreement. The information can also be reached on the Internet and on the electricity meter, and the whole idea is to give the consumers an ability to adjust the energy use taking into account the current price of electricity. There are also possibilities with direct load control, for example water heaters connected to the meter via a special entry in the electricity meter. Available quantity of hot water can be adjusted, for example reduced in case of red days. There are eight different programs for adjusting the heat in the device, depending on how much you want to save and how warm you want your house to be (Badano, et al. 2007). More optional smart home services are also offered to the customers:

- *"Take control of your consumption"*: The customer can see consumption data for electricity, water, and gas (with the system using radio transmitters at the respective meter) during billing period in Euro and kWh, showing which days had the highest consumption. An alarm can also be sent (by email or phone) if consumption cost has exceeded a limit set by the customer.

- *Alarm service*: A 24h alarm system is connected to the device, which reports to an emergency company
- *Heat control*: The service has been available since 2007, which implies that an optimum heat program is tailored to the customer's lifestyle and enables the heat to be adjusted via the Internet (Badano, et al. 2007).

Power output has dropped sharply during red days with Tempo. By the end of 2004, about 400 000 customers had chosen the tariff service. As many as 90 percent of these have been satisfied or very satisfied with Tempo, reducing on average the electricity bill by 10 percent. Many red days in a row, on the other hand, has not been popular (Badano, et al. 2007).

Smart metering in Sweden

In accordance to what was explained in the previous chapter, about 5.2 million end customers in Sweden, where of 4 million households customers, have from 2006 until 2009 been provided with meters that can be remotely read. The meters have the functional requirement of being read at least once a month. This means that the new standard electricity meter indeed has given new features that can be considered as feedback for homeowners, but, according to ESMA, when implementation started several years ago many DSO's selected simpler technologies (ESMA 2009). This is also the consequence of the simple monthly read policy; the Swedish smart meters have no requirements on prepayment functionality, configuration of tariffs, or any in home communications or display (Meterpedia 2009). As a result, the functionality and performance of the smart metering systems varies significantly. According to ESMA, about 10-15 percent of these meters are in metering systems not capable of much more than monthly reading. They are remotely readable, but far from being referred as smart metering. Most likely, they could be replaced during the coming years well before their technical life time (ESMA 2009). A large proportion of the meters do have equipment installed that allows recording of consumption per hour, but infrastructure for collecting and processing measurement data set the limits. Meter readings are sent once per day. The technical and financial constraints for providing detailed and continuous information, or at least hourly, of the overall electricity consumption for Swedish households does not likely appear in the measurement itself. The constraints are rather in how the information will be sent to the electricity company.

Figure 5.1 – Actaris (left), Iscraemeco (center) and Telvent (right) models, installed at customers of Vattenfall (Vattenfall 2007, Vågbrytaren Stockholm 2008)

According to Vattenfall Customer Service, hourly measurements are to date only offered to business customers. Residential customers are not so interested in such detailed measurement, or at least not yet (Vattenfall Customer Service 2009). The hourly measurements are given to about 8000 business customers, primarily using the Iskraemeco meter, but the Telvent (Echelon manufactured) meters (installed in 590 000 households) are also already set for hourly collection (Swedenergy 2008) (Vattenfall Eldistribution 2007). The Vattenfall meters are shown in *Figure 5.1*.

Usually the standard meter is composed of three main components. Those are the meter, the meter switch, and the communications terminal. Most meters are equipped with a display showing the electricity use (in kWh), and set with a toggle function where more information can be provided. The information usually involves electrical data, for example instantaneous phase-specific voltage, but can vary widely between different meters as the network companies have chosen different solutions. For example, meters from Mälarenergi are restricted, and can only provide electricity use (kWh) together with instantaneous current and voltage for different phases. Along with additional electricity data, the meters from Göteborg Energi, by the Kamstrup model, can give the instantaneous electrical power (kW) which in this report is defined as real time feedback. All meters located at customers of Vattenfall can show the electricity use for different time-of-day tariffs. Vattenfall has provided customers with documentation on how to calculate the instantaneous electrical power by using the new meter (Vattenfall 2009). In Swedish homes the meter is usually located at the fuse box or outside the house in a cabinet. The energy user will need the meter within visual reach, and count the number of pulses given by the LED[4] (marked 1000 imp/kWh) for a fixed period of time. The following formula, which gives a value of the total electrical power (kW) for the household, can then be used:

[4] LED is the commonly used abbreviation for Light Emitting Diode.

$$P = \frac{n \times 3600}{t \times k}$$

(Equation 1)

Where P = instantaneous electrical power (kW)

n = number of counted pulses

t = time (s)

k = number of pulses per kWh given on the front plate (Vattenfall's meter uses 1000 imp/kWh)

As an example, if the electrical load consists entirely of a 1000 W electric heater, it will take approximately 3.6 seconds between the LED flashes. Accordingly, painstaking home-owners have the capability to, with existing technology, calculate their total electricity output. Whether or not obtaining data on energy feedback by own calculation is thought of as practically difficult or a limited method among homeowners, which is not further investigated in detail, more detailed solutions will be presented in this thesis with a more obvious practical ease. Due to the workload required, it seems that just waiting for the monthly bill is the easy way out for the ordinary Vattenfall customer. Pulse meters suitable for doing this task, combined with a display, or other ways of presenting data, have in recent years been developed by niche companies. Examples are given in section 5.2. Customers with a computer and internet access can, however, follow the electricity consumption on a profile page at Vattenfall's website. The monthly bill can be of different kinds, which probably also has some effect as well on the visibility of the energy use. Customers with regular or electronic invoice are likely to have better position to keep an eye on their energy use, rather than customers with direct debit.

To fulfill the requirement of monthly readings, the network companies have chosen different solutions. The variety of technologies used is due to the circumstances that each of the network companies have faced. Geographical location and housing density, together with respective company's given technical prerequisites are just a few possible reasons for the suitable choice of technology. *Table 5.1* presents a compilation of the outcome for the five largest network companies. The chosen communication technologies, for carrying the measurement data, among the selected companies are:

- The mobile network (GSM, GPRS)
- The power lines (PLC)
- Radio (RF)
- Fiber

An additional option, also included in the report for decision-taking (Swedish Energy Agency 2002), was to use the public telecommunications network. This option does not seem to have gained much support, or at least not in any of the solutions by the selected major companies. As with the other Nordic countries, the Swedish smart meter implementations tend to favor GPRS or GSM solutions (Meterpedia 2009).

Network Company	Installed AMR in households (total customers)	Supplier of meter	Communication technology at households / base station or concentrator to AMR central system (if known)*
E.ON Elnät Sverige AB, including Stockholm	(980 000)	• Actaris (~27 000) • Echelon (~390 000) • Landis+Gyr • Enermet	• GPRS • PLC/GPRS, Fiber • PLC /GPRS, GSM • PLC
Vattenfall Eldistribution AB	(850 000)	• Actaris,Senea (~110 000) • Iskraemeco (~150 000) • Telvent,Echelon (~590 000)	• RF/GSM • PLC/GPRS P2P • PLC/GPRS
Fortum Distribution AB	(835 000)	• Actaris • Landis+Gyr (~150 000) • Powell MDMS • Siemens	• GSM • GPRS • PLC/GSM • PLC/GSM
Göteborg Energi Nät AB	(275 000)	• GE (1-phase) (~90 000) • Aidon (3-phase) • Kamstrup (3-phase) (~100 000)	• RF (ZigBee)/GSM, GPRS, Fiber • GSM, GPRS, Fiber • RF (ZigBee)/GSM, GPRS, Fiber
Mälarenergi Elnät	98 000 (140 000)	• Kamstrup (~25 000) • Actaris (~73 000)	• RF • PLC/GSM P2P, Fiber
Remaining 190 network companies	~2 120 000	-	-

Table 5.1 – Compilation of DSO's and metering systems (Energimagasinet 2006, Göteborg Energi 2009, Göteborg Energi 2009, Meterpedia 2009, Mälarenergi Customer Service 2009, Vattenfall Eldistribution 2007)
**Meters are usually equipped with several communication technologies ,the table gives only a rough idea of quantities and equipments, the data are not precise for all types*

A number of smaller DSOs, have worked in a consortium of 33 to combine their buying power to represent around 20 percent of the market. The consortium took the name Svenska Mätsamarbetet (SAMS), and serves a little more than a million customers. Almost all of these customers have Echelon meters installed (Meterpedia 2009). A list of the DSO members of SAMS is given in Appendix B.

According to Vattenfall customer service, the household meters have currently no known technical lifetime expectation, but there are tests that determine how long the meter can be in use, referring to the SWEDAC regulations presented previously in section 4.3. Furthermore, it was explained that the old meters had prescribed regulations, and were submitted to revision after 18 years of use, but those rules have now been abolished. There is today no maximum limit on how long an electricity meter may be in use, instead the periodic inspections will determine how long the installed meters will be in use (Vattenfall Customer Service 2009).

As a result of the new standard meters, additional services have been offered for many customers. Electricity companies have during the last decade, in varying extent, begun to offer a range of online services on presenting historic consumption and cost for the customers. In general, the meter itself or its display has to date no function on for instance historic or comparative feedback (will be fully explained further down). Nevertheless, many home-owners and electricity consumers may, at least in the near future, most likely gain access to this kind of information. Since many of the new meters can store consumption data to be transmitted to the electricity company, the information could be available through the company website. One should, however, be careful to regard the information as sufficient feedback since the 24 hours values of consumption data usually is delivered daily to the company, before it in return can be presented to the customer. One of the three main electricity companies E.ON has announced multi-stage future plans with the intention of delivering electricity consumption data hourly to all customers, including households, with the service *Energidialogen* (E.ON 2009). As explained further in Section 5.2, the feedback should be delivered quickly to the electricity users to enable them to adapt their actions to the reported consumption. In this study, this is also a prerequisite for the reported information to be considered as feedback.

Echelon meters dominating in Europe

With many meters installed in Sweden and especially in Italy, Echelon's technology is so far the most widespread for building controls and PLC technology in Europe. Echelon's system has, however, been less popular in the US, where most utilities have opted for radio mesh or other wireless communication to connect smart meters, citing the higher costs associated with power line networking. As for home energy monitoring and control systems, Echelon is already working with Samsung electronics for devices that monitor energy use in apartments in China and Korea. Apartments are natural venues for PLC, since the distances between meters (often located in the basement) and apartments above make wireless communications difficult. Echelon's power line signaling technology for carrying data from a smart meter over a building's electrical wiring is competing with other standards. Another PLC technology is being developed by the HomePlug Powerline Alliance, a group of companies that is working together with the ZigBee Alliance (developing wireless products based on open standard) to integrate their efforts to bring communications technology into homes. According to a Greentech Media article published in March 2009, director of corporate marketing Steve Nguyen comments on as for using ZigBee instead of power line signaling, Echelon’s smart meters can be retrofitted to carry ZigBee radios, though no customers have done so yet (Greentech Media 2009).

5.1.3 Concluding remarks regarding standard electricity meters

In the light of what has been presented in this section, the following has been acknowledged on the standard electricity meters installed in households.

- AMR deployment occurs over large parts of the world, where Europe and the US can be considered to have made the biggest progress with its expansion.

- Variations of AMR meters exist, where countries around the world have different conditions, needs and desire for implementing different types of technology. Member countries of the EU follow the directives specified by the EU Commission.

- In Sweden, and in accordance with established regulations and principles, households are provided with information on their overall electricity consumption at least once a month in combination with billing. In most cases, the measurement is made per hour, and meter data is sent daily. Households wanting to take part of meter data more frequently, can use web services if available, or read and follow the meter display on their own.

- The technical life time of the AMR meters in Sweden is hard to estimate, periodic inspections will determine how long the installed meters will be in use.

- Some DSOs in Sweden have plans of providing measurement and reporting per hour for residential customers, but it is uncertain when this will happen. The legal requirement is set on a monthly basis.

5.2 Feedback types

The rapid growth in consumer electronics is counteracting the benefits from savings in lighting, cold and wet appliances: people typically buy a new appliance for the service that it can provide, with little thought of the consumption, and fast-changing consumer electronics are notoriously resistant to labeling. So the case for raising awareness is a strong one. Basic real-time displays (which may not be very accurate, reliable or well-designed) have been surprisingly effective in the hands of motivated users, although their shortcomings have left them unused or abandoned by others.

(Darby, Frankish, et al. 2009, 36)

According to Oxford University researcher Darby, monthly bills on average provide 5 percent of electricity savings for households. Darby has summarized results of 40 international studies of intelligent electricity meter solutions[5], providing information at a fast rate with real-time feedback (also called direct feedback). Figures on real-time feedback have shown savings between 5 and 15 percent of the electricity consumption (Darby, Frankish, et al. 2009). Darby uses the expression of indirect feedback when the customer does not have easy, direct access to the meter and consumption data, and relies mainly on bills or statements (Darby 2006). As noted in the quotation above, one of the benefits of gaining electricity feedback is that people can raise the awareness of their own usage. Whatever outcome this awareness may provide, in this study it is assumed to function as a tool to create opportunities for learning and developing conservation strategies. Established nationwide implementations are yet to come for providing results on savings, but they may be hard or even impossible to measure in full scale if measures from other incentives are carried out simultaneously. In-home solutions can involve controlling,

[5] The expression of intelligent electricity meter solutions is chosen since they can be linked to smart metering (as explained in 5.1.2), but they do not necessarily have to since it can also involve other types of in-home metering solutions for example “clamp-on”.

possibly providing savings directly without any workload for the household, or they can provide savings as a consequence of behavioral changes or replacements of in-home products, where the equipment of providing feedback could play a significant role. According to Darby, feedback is of value in itself as a learning tool and must be seen in context. The outcomes from feedback will vary according to circumstances, but they can also sometimes be improved by using feedback in conjunction with advice and information (Darby 2006).

There are numerous possible ways to provide homeowners with energy feedback. What is more difficult to determine is in what way, and for whom, the feedback can be most suitable. Most probably, a house-owner with annual electricity consumption over 20 000 kWh could be inclined towards reducing costs. Apartment owners might be just as interested in reducing electricity consumption for any reason, for example environmental reasons. Of course, it is also reasonable to assume neither of the two might want to deal with the electricity consumption for many possible reasons. This would mean obligatory measures must be applied if lower electricity consumption is to be achieved in households.

The products presented as examples of commercial solutions in this chapter are in most cases for sale to end-users, such as ordinary households. But in some cases the products are intended for customers involving several different markets, for example projects and field trials run by companies or government agencies, and OEM[6] systems integration for energy and Home Area Network (HAN) markets.

Design choices and feedback modes

Although this thesis has little to do with the designing of feedback or displays, but rather has its focus on concepts, there are important aspects to consider when presenting the information. Darby highlights the importance of distinguishing between advanced metering and providing good feedback, which is not the same thing, and the need of effective displays (Darby 2008). Mode choices for designing displays can usually involve, single or combined:

- *Ambient mode*: Ambient feedback is aimed at peripheral vision, not at supplying detail, for example with colors where green means low consumption, amber for medium and red for high. Ambient feedback gives the user an indication of what is going on, without requiring detailed attention, and alerts the user if unusually high consumption is reached.
- *Analogue mode*: Careful use of graphical displays can illustrate the scale of consumption even without detailed numbers.
- *Digital mode*: Digital information gives accurate and useful data (Darby, Frankish, et al. 2009).

If one seeks minimum use of materials it is possible to use any display that already exists inside the house, where accessibility is important. A web-based display can be accessed from anywhere, as with a mobile phone display. If a separately and assembled display is to inspire the household, it has to show consistency with its purpose, to save energy, and it has

[6] An Original Equipment Manufacturer makes equipment or components that are then marketed by its client, another manufacturer or a reseller.

to be demonstrably useful over long periods of time. If the display is to be moveable, with the compelling argument for an electricity display to be moveable so that it can be taken around the home while the user switches different items on and off and notes the impact. A moveable display will require some kind of batteries and extra in-use energy in order to receive data.

The following different feedback types investigated are

- Real-time feedback
- Historic feedback
- Predictive display
- Comparative feedback
- Variable pricing feedback
- Own-generation feedback

The naming of terms used has been carried out logically by Darby (Darby 2006, Darby et al. 2009), and are also used for the following titles.

5.2.1 Real-time feedback

Real-time feedback is the category associated with the first-generation display with information on electricity consumption. The function would be to provide instantaneous information on consumption from the meter or a connected display monitor. Most real-time displays to date also have the ability to show cost on the same screen or by toggling between the two (Fischer 2008). The cost is usually only a cost per hour based on instantaneous consumption, and is a lot less reliable than any figure based on cumulative consumption over a given period. According to Darby, studies made suggest that people in general are more interested in the figure for cost or load (kW), rather than on any given figures for associated carbon emissions (Darby, Frankish, et al. 2009).

The role of the meter is to provide a clearly-understood point of reference for improved billing and for display, for example by identifying the largest consumers by switching on and off appliances. In case there is no separate, free-standing display then the meter should be clearly visible within the building in order to receive the information the feedback is providing. According to Darby, studies and pilot projects have shown that real-time feedback produces savings of around 10 percent against control groups. The norm is for savings to range from between 5 and 15 percent. There is some indication that high energy users may respond more than low users to direct feedback (Darby 2006). The *OWL Micro*, a wireless display shown in *Figure 5.2*, is an example of a product providing real-time feedback on electricity cost, which also has a cumulative function for costs accumulative over daily, weekly, monthly or on annual basis. The price is £24.99 plus £5.95 for the sensor required for 3-phase installations (the product is only configured for UK currency and voltage).

Figure 5.2 – The OWL Micro display, providing real-time feedback on cost (John Lewis Partnership 2009)

Products having the sole purpose of providing real-time feedback are slowly becoming rarer to find. Many solutions are developed, combining real-time feedback with other types of feedback that will be presented below. The types of feedback that follow are all compatible with real-time feedback, for example as options on a display.

5.2.2 Historic feedback

With historic feedback the user is given data on cumulative usage, to give comparisons and information on energy use for a given period. Preferably the comparison period can be given by the user's own choice of reference, for example how much electricity did the household use last month compared with the same time the previous year? (Darby, Frankish, et al. 2009) When using historic feedback it can also be useful to correct for the outdoor temperature variation. This can be done by using the method of degree days, which gives an indication of how the temperature has deviated from the normal temperature. Degree days can in this context be regarded as a way to provide fairness notions on a building's energy consumption for heating, which are often highly correlated with outdoor temperature. For example, when comparing the electricity use for the new heating system with the replaced system both used during the winter season, and the outdoor temperature has been very different between the winters, using degree days or not may well have a significant impact on the result.

According to Darby, units of energy are likely to be more effective than units of costs when displaying historic feedback. They might be less intelligible to the average person or the household as whole, but as comparative figures they seem likely to be more reliable. If the metering system uses any kind of automatic update of price, changes in the unit cost of electricity or fuel over time will be able to sabotage the energy user's perception of how consumption patterns are changing. There can also be a risk so as to displaying cost savings could actually backfire for some energy consumers, as it could show figures that are considered too trivial to matter (Darby, Frankish, et al. 2009). If any trivial figures on energy saving are capable of producing the same outcome is not commented by Darby.

UK based Green Energy Options has developed *the Solo*. Apart from showing expected carbon emission and cost, it also provides a comparison of the current electricity usage to usage last week.

Figure 5.3 – The Solo display by Green Energy Options, equipped with historic feedback (Green Energy Options 2009)

5.2.3 Predictive display

In addition to the historic feedback, setting targets or budgets for the future through predictive displaying are a conceivable alternative. When reducing energy use by consumption pattern, the predictive display can indicate how successful the energy user is being in relation to moving towards the targets (Darby, Frankish, et al. 2009).

BeAware is a collaborative research project co-funded by the European Union, with the mission to study how a wireless sensor in real time can be used to increase energy awareness and reduce consumption in households. The project was started in the spring of 2008, consisting of partners from research departments at universities and companies in the energy sector in Sweden, Finland and Italy. With the prototype *Energy Life* the user is given information and feedback to a mobile interface, and by cues and signals from the existing lights either by a dimmer or flash signal. The user can set different targets, and is given information on for example if the TV has been used for more than two hours today. The concept is shown below in a screen shot taken from a video presentation on YouTube.

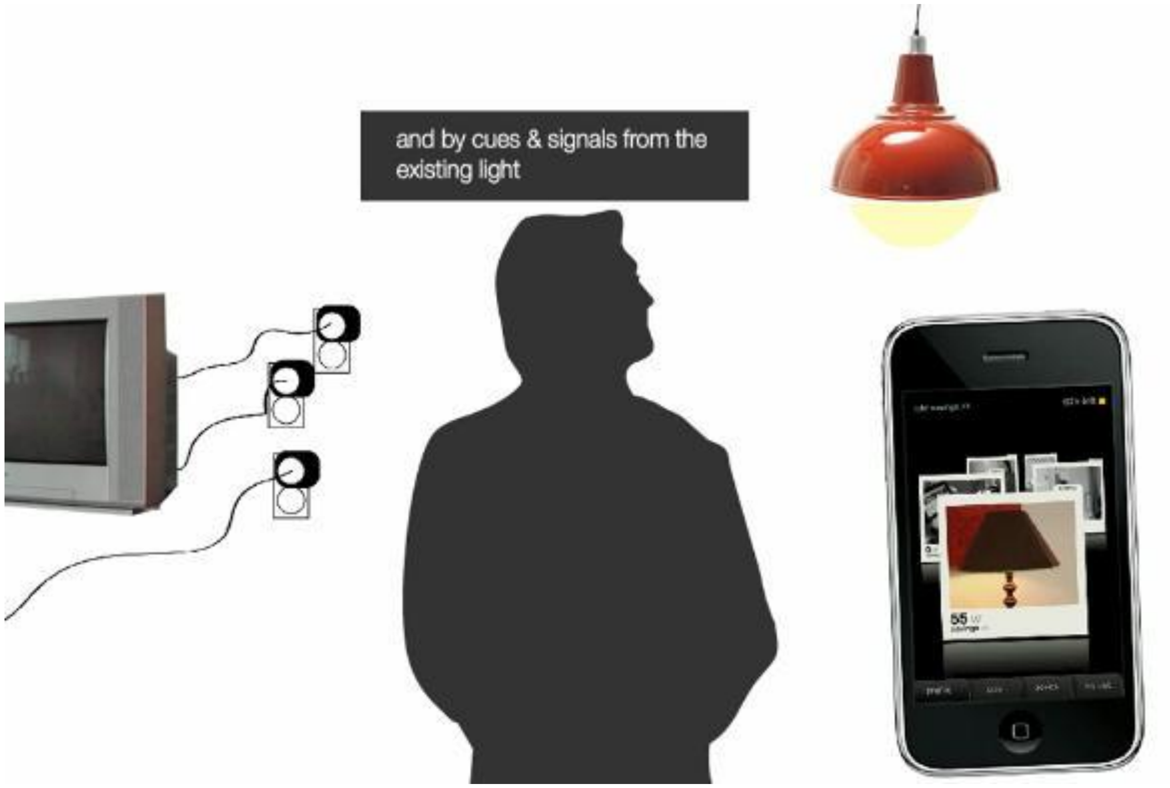


Figure 5.4 – Energy Life by BeAware (Interactive Institute 2009)

5.2.4 Comparative feedback

Comparative feedback, also called normative feedback, gives comparisons with a reference group of energy users. The reference group can be an assortment of individuals, for example people with a comparably-sized and similar home or neighbors in the same area. The reference can also be a significant metric on average figures of for example energy consumption or carbon emissions per household for the country (Darby, Frankish, et al. 2009). There are many varieties of comparative feedback examples often combined with predictive display, making it possible to play energy conservation games, for example within the household or with neighbors. For the in-home device with a simple display, comparative feedback might be an ambitious metric, but far from unfeasible. For the network companies with many customers, though, this kind of feedback should be more or less easy to provide for households. In Sweden, in other member countries of the EU and in the US there are also easily accessible public statistics that ought to give the opportunity of making this kind of feedback feasible in all of those areas.

According to Darby, it is most likely that comparative feedback may be useful on occasion as a way of awakening interest or checking a household's energy use in relation to other households, but is not the most useful type on a regular basis (Darby, Frankish, et al. 2009). *Google PowerMeter* is free energy analysis software that can provide a consumer with electricity usage monitoring, through a Google gadget on the user's iGoogle homepage. To use the tool the user is required to have an installed smart meter by a Google Utility Partner, or a consumer-owned electricity management device. So far, a dozen partnerships have been reached, including the German electricity company Yello Strom and the device company The Energy Detective. The Google PowerMeter demo shown in *Figure 5.5*, is expected to spare electric utilities and other partners, from large web resources needed for all those customers who call for detailed information about their electricity consumption. The software so far seems to have the ability to provide a number of feedback methods, for example comparative, historical, and can provide the consumer with important information delivered by the electrical company, such as time-of-day price or critical information on blackouts. There will be more functions to come in the future since the tool is currently under development.

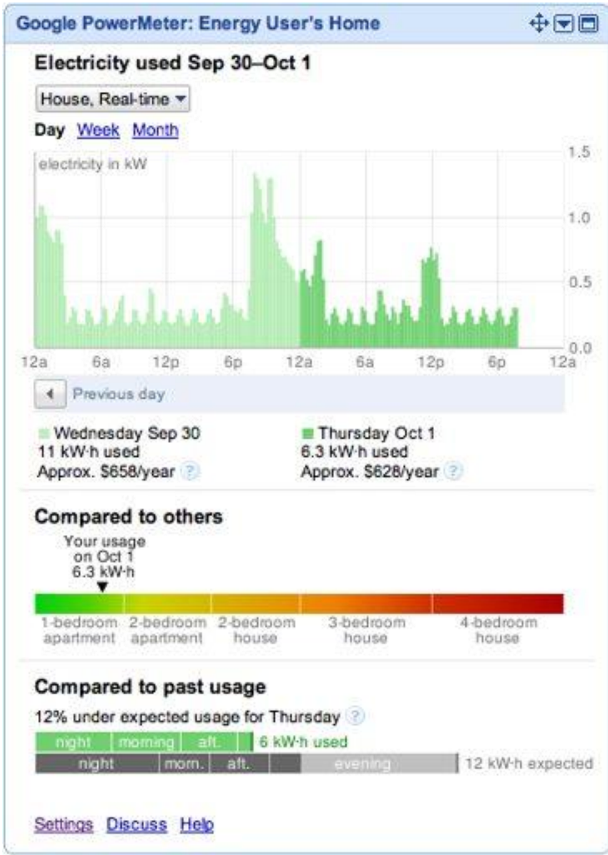


Figure 5.5– The Google PowerMeter, providing web based information on electricity consumption including comparative feedback (Harrison 2009)

5.2.5 Variable pricing feedback

With variable pricing feedback households are supposed to receive instant information on variable tariffs (Darby, Frankish, et al. 2009), thereby leading to a reduction in use when the price is high (and possibly higher when price is low). The method has mainly been advocated as an advantage for electric utilities to reduce peak load. For the group of electricity customers who have such an agreement, the method is possible. So far, however, not many ordinary households in for example Sweden or the UK have time-differentiated tariffs. Despite the expected benefits often mentioned, it is still unclear if the form of agreement will be common for regular households in the future. According to ESMA, there are some ongoing tests with real time tariffs by Swedish electricity companies (ESMA

2009). Italy, probably at the fore-front of European smart grid technology and deployment, has recurring problems with peak load both during winters and summers. This has lead to the fact that several Italian DSOs have invested in AMM technology with support for variable prices. Most famous is the ENEL Telegestore project with more than 30 million customers, which, together with The Italian Energy Authority (AEEG), has given guidelines of the AMM with a defined standard time-differentiated tariff. High price is between 08:00-19:00 Monday to Friday, and low price all other times. It is determined for all AMM systems installed in Italy to support time-differentiated tariffs, with this division of time for pricing (Badano, et al. 2007).

According to Swedish Elforsk, coordinating industry's joint research and development, any individual household consumption is relatively low compared with commercial and industrial customers. Households as a collective, however, are still interesting from load management perspective, especially as they often contribute relatively high to the peak size since electricity consumption is very strongly related to the weather. To decide if the variable prices should be mandatory or voluntary is not easy. Mandatory programs require large investments, but voluntary programs may risk being unfair. Customers involved and adjusting their load can save money, but the savings will increase even more for the rest of the customer community since the reduced volatility will give lower prices (price movement) in the spot markets. Moreover, it can also happen that the customers who first join voluntary programs are those that already consume most of their electricity outside the peak periods occur. These customers can then reduce their costs, but the peak load will not be affected (Badano, et al. 2007).

Most probably, this type of pricing and feedback could lead to cost savings within a household. Regarding energy conservation, however, reducing peak load may indeed be in a consumer's and society's wellbeing, but that the variable pricing feedback additionally leading to reduced energy consumption within the household is doubtful. *Figure 5.6* shows the smart metering enabled *Energy Joule*, with variable pricing feedback in its capacity of changing color after price of electricity.

Figure 5.6 – Energy Joule (Ambient Devices 2009)

5.2.6 Own-generation feedback

According to Darby there is evidence of obtained energy conservation when households are aware of the existence, extent and timing of any electricity generated on the premises. Part of the rationale for smart metering is that it can record both imports and exports of electricity and is necessary for smart grids that can optimize the balance between load and supply. (Darby, Frankish, et al. 2009).

5.3 Disaggregated electricity feedback

Feedback techniques, with products and prototypes, presented in Section 5.1 have all dealt with the function of measuring the total electricity for a household, given aggregated on a display, with the exception of the Energy Life prototype. In order to determine energy consumption for individual appliances, for example electronics such as TV, computer, or heating systems, the user is required to move around the house and switch appliances on and off to distinguish them from each other.

The method can only work if it collects real-time feedback, but it does not give detailed data over time. The appliance specific information will only be available for a short period of time, and the method cannot give the appliance specific consumption information over time. For example if a home owner notices an increase in electricity consumption, it could be difficult to know if there is a failure in any equipment or appliance, or if it simply is someone in the household who have begun to use more electricity than before. The home owner will presumably have to go through the house once again and switch everything powered by electricity on and off. To measure the overall electricity for the household, the technology is not more advanced than for example counting pulses of the existing standard meter (the smart meter), or measuring with a clamp-on sensor at the main input electricity cable. Once the meter equipment is in place, the data can continuously be sent to a wireless display or device using radio, and so the search for energy villains begins. Darby also points out the importance of separating space heating from the other end-uses, when a dwelling is all-electric. If this is not done on a display presenting real-time load curve, the size of the heating load is likely to drown the real-time feedback signals that would otherwise show up clearly when an appliance was switched on or off (Darby, Frankish, et al. 2009).

Fischer stresses the importance of providing disaggregated feedback for establishing awareness.

Providing a breakdown, for example, for specific rooms, appliances, or times of the day is provided, is almost the only way of providing a direct link between action and result and thus, establishing consciousness of the relevance of individual actions.

(Fischer 2008, 85)

A breakdown of the energy consumption is important for several reasons. Although Darby notes that end-use disaggregation identifying appliance “signatures” is likely to be unfeasibly expensive, she says that the argument rests on the educational effect in raising awareness of the relative demand from different appliances. Furthermore, it is noted that feedback that is disaggregated by end-use at the electricity meter can be relatively expensive and complicated to supply, while an accessible display showing instantaneous information is advocated. Information on which end-uses consume most energy is, however, seen as useful by many households. When 1 000 Norwegian households were given a pie-chart on their bill showing a typical breakdown of six main domestic end-uses, 81 percent of respondents thought it useful and 38 percent appeared to have learned something new from it (Darby 2006). Fischer has presented features for successful feedback, which will both stimulate conservation and be satisfying to households.

According to Fischer, such feedback

- is based on actual consumption
- is given frequently, and ideally, daily or more often
- involves interaction and choice for households
- involves appliance-specific breakdown
- is given over a longer period
- may involve historical or normative comparisons, although these are appreciated by households, the effects are less clear
- is presented in an understandable and appealing way , designs should be based on sound consumer research (Fischer 2008)

Both Darby and Fischer show that there are hardly any studies on potential savings that disaggregated feedback may produce. Fischer gives an example with a field experiment (Dobson and Griffin 1992) in 100 US households including 25 in the experimental group and with two control groups, where continuous feedback on consumption and cost was broken down to various appliances and time intervals during an average of a 60 day period. The finding from the field experiment was that consumption was about 13 percent less than in the control groups (Fischer 2008).

5.3.1 Appliance-specific feedback

Appliance-specific feedback should be useful for investigating the electricity consumption for individual appliances. In the search of a breakdown of the household's electricity consumption, this is the ideal breakdown.

This feedback can be given by using a basic appliance specific meter with display, for example a plug-in electric power meter. The meter is typically placed into a wall socket, and the device to be measured is plugged into the meter. Or, as with some meters, the plug is attached to the main body of the meter by a cord. The meter measures the electric current going through, and provides information on for example power, electricity consumption and cost for the specific device. There are many varieties and functions to choose among, a few examples are shown in *Figure 5.7*. It is also feasible to imagine the possibilities of a perhaps better-looking solution with installing "smart sockets" in a house, where the sockets are equipped with metering and communication equipment. This might need an electrician though, making the solution much more expensive for an existing house. Examples of such sockets have not been found, but there is plenty of such control equipment appropriate for households on the home automation market.

The cost for a plug-in electric power meter depends most likely on the amount of features and the accuracy provided. In recent years, wireless models have also been developed to transmit information to a central computer with monitoring software. Examples of wireless products are UK based *Plogg*, and products by the Dutch company *Plugwise*. Both models can transmit information to a computer via a wireless mesh network[7], such as Zigbee, and

[7] In a mesh network, the connected devices communicate with each other and not only with a central.

have remote control giving the user the ability of switching the connected device on and off.

Figure 5.7– Plug-in electric power meters. Basic on the left, wireless models in the center and on right (Vattenfall 2009, Vesternet 2009, Hekker 2009)

The price for a basic plug-in meter is in Sweden from 169 SEK (PriceRunner 2010), and the web price for a Plogg-device with a USB Stick dongle is 127 £ (Energy Optimizers Limited 2010). A Plugwise system including two plug-in meters and a USB Stick dongle is at 1395 SEK (Freiholtz Consulting 2009).

Communication technologies and consortiums

There are many communication standards intended for in-home solutions. Home automation, also called domotics, may pose an increased automation of household appliances and controllable applications. For many people, this is what a smart home might be equipped with. With wired communication, the standards can use added communication and control wiring, or embed signals in the existing powerline. Solutions using standards of radio frequency (RF), may be easier to retrofit into an existing house, but the wired, on the other hand, might be more suitable for long distance or at least have no problem in transmitting, for example through the walls. Some standards can also use a combination of several methods. The following table provides a number of standards.

Technology	Method	Medium	Classification
Ethernet	Wire	Optical fiber	Data
FireWire	Wire	Optical fiber/twisted pair	Device interconnection
HomePlug	Wire	Powerline	Data
X10	Wire	Powerline	Control and automation
LonWorks	Both	Powerline/twisted pair/optical fiber/RF	Control and automation
INSTEON	Both	Powerline/RF	Control and automation
KNX	Both	Powerline/twisted pair/optical fiber/RF	Control and automation
UPB	Wire	Powerline	Control and automation
Wi-Fi	Wireless	RF	Data
Bluetooth	Wireless	RF	Device interconnection
ZigBee (layer)	Wireless	RF	Control and automation
Z-wave	Wireless	RF	Control and automation

Table 5.2 – Some of the standards and protocols used for home automation

A standard is normally produced by a group of companies agreeing on a particular technology, which the companies then use in their products. Examples of consortiums are the HomePlug Powerline Alliance with 73 members, the Z-Wave Alliance with over 160 members, and the ZigBee Alliance with over 330 members. The ZigBee Alliance is also a member of The Demand Response and Smart Grid Coalition (DRSG) with another 48 networks or companies, which is the trade association for companies that provide products and services in the areas of demand response, smart meters and smart grid technologies (DRSG 2010).

Recently the National Institute of Standards and Technology (NIST) announced the first of two publications of Smart Grid Interoperability Standards for the US. The standards, with a number of 25, apply to different parts of the Smart Grid including data protocols, communication protocols and security standards. The second step will be in seeing which of the various standards the industry implements in a large scale (National Institute of Standards and Technology 2010). In the list of different area needs, one of them is addressed by the HAN standard, including home automation. Both ZigBee/HomePlug and different powerline networking solutions are noted. Of course, DSOs, electricity companies and others can build interfaces within their space, but the most probable way for such smart devices and smart appliances to take off in homes is for an open interface that can be utilized by any manufacturer in the world. In the report, different needs and opportunities are being discussed.

Ideally, a consumer would purchase, for example, a smart grid-enabled clothes dryer, plug it in, and register it with their service provider through a Web portal or toll-free phone call. That is all that should be necessary to enable a "smart" appliance to operate on the basis of electricity price information and other demand response signals received from the smart grid.
(National Institute of Standards and Technology 2010, 42)

Going back to the appliance-specific feedback, plug-in meters or the possibility with future plugged in "smart" devices, can give detailed information for the specific appliance. If there are many appliances in a household, however, it will require just as many measurement points in order to get a full briefing. Today, there are no smart grid-enabled clothes dryers, except for using a plug-in meter that is smart grid-enabled. The appliances to undergo measurement providing appliance-specific feedback are restricted to appliances using a plug connected to a wall socket. Using the plug-in models of *Figure 5.7*, one can usually not get information on the larger electricity consumers within a household having directly-fed electricity.

5.3.2 Grouped-appliance feedback

Another possibility of giving detailed information on the electricity consumption is by measuring grouped appliances in a household. This method might give less detail than the appliance-specific feedback, but the amount of information for a comprehensive measurement of a household's electricity consumption can also be smaller and possibly for the household easier to take in. Monitoring every single appliance on electricity within a household might give an undesirable amount of information. Logical divisions of a household’s electricity consumption could be by room or activity, and with the opportunity to have specific measurements of the largest electricity consumers such as a heating system.

Although there have been no specific products found for the measurement of groups of devices during the time of writing, except when attaching a plug-in meter for a device with several plug opportunities, there have been products found that could provide electricity companies opportunities for load control of customers' high-voltage devices. One example is Sequentric's *current transformer encoding module*, which is featured with a long life, 30 ampere contactor that can remotely enable or disable a variety of loads. The module provides load control of devices such as water heaters, pool pumps, dryers, and battery chargers for electric vehicles and utility battery packs (Sequentric 2009). With load control, disconnections and reconnections of the devices’ electricity circuits can be carried out for example by direct contact with a relay in a household’s fuse box, and could be performed for example in conjunction with expected high price hours for time-of-day tariffs. If the load control equipment also includes measurement equipment, electricity companies, who own the equipment, may choose to provide their customers with information about the disaggregated consumption.

Figure 5.8 – A fuse box provides an in-home electricity consumer breakdown (Optus Electrical Pty Ltd 2009)

An already made division of electricity consumers in all households is possibly at the fuse box. By measuring by each fuse, automatic fuses shown in *Figure 5.8*, joined groups of electrical devices would be shown but also some specific appliances in the household with high energy use would be discerned. The division would vary from house to house, and be completely dependent on how the electrical installation has been made. Most likely, an electrician would be needed for installing such equipment. An example of a two-floor house with direct electric heating has the following breakdown of the fuses, given in *Table 5.3*.

Group No	Group comprises Central A1	Rated current of fuse	Area mm2
1	Heat ground floor	10 Amp	1.5
2	Heat upper floor	10 Amp	1.5
3	Stove	16 Amp	2.5
4	Washing machine	10 Amp	1.5
5	Fridge and freezer	10 Amp	1.5
6	Water heater	10 Amp	1.5
7	Heating loop ground	10 Amp	1.5
8	Dishwasher	10 Amp	1.5
9	Socket laundry room	10 Amp	1.5
10	Lighting and socket kitchen, laundry room	10 Amp	1.5
11	Lighting and socket living room, bedroom 1	10 Amp	1.5
12	Lighting and socket ground floor hall, toilet	10 Amp	1.5
13	Lighting and socket upper floor hall, bathroom, bedroom 3 and 4	10 Amp	1.5
14	Lighting and socket bedroom 2, closet	10 Amp	1.5
15	Maneuvering heat	10 Amp	1.5

Table 5.3 – Fuse chart for a two-floor house with electric heating

As the information from a fuse chart shows above, measurements over fuses should get a quite comprehensive and detailed picture over the electricity consumption in a house. The less detailed groups, though, for example several rooms, with sockets or lighting included for fuses, will provide more aggregated information.

Energy monitoring software

The UK based company Sentec has developed the software called Coracle, which can by DSO's be deployed in the field by downloading new firmware to the right smart meters. It can be integrated in the HAN, or deployed on a server for web-based applications. According to the product sheet, the household can receive information on overall consumption, but also on appliance-level consumption for some high electricity consumers. An example is given with lighting and TV as grouped together, while the dryer, dishwasher, and oven are listed separately. Solutions can range from a simple in-home display, to interactive web-based reports that deliver customized recommendations based on preferences and tariffs (Sentec 2009). Since the software calculates the electricity consumption for individual appliances, instead of measuring, the solution will probably be cheaper, but the precision of disaggregation is probably considerably reduced. It is possible that devices with stable load are able to identify, but since a lot of equipment in a household vary in power consumption this should present difficulties when achieving a comprehensive picture of the electricity consumption. The system might need to be supplemented with specific meters, such as clamp-on sensors, depending on the level of desired comprehensiveness.

6. Customer survey

This section presents the results from the performed customer survey. Although literature has been found claiming the importance of improving electricity consumption information to customers, for raising incentives, asking house-owners directly should be the best way of finding out. Interviews have been performed in order to get the house-owner's point of view on the electricity consumption within the household and other relevant matters connected. The interview template (Appendix C, in Swedish) was designed with predefined answers to most of the questions asked, but the subjects were not informed about them unless needed and in case they had difficulties in explaining their opinion. All subjects were interviewed individually, and were mostly carried out in the evenings. Responses and answers were transcribed instantly for all questions asked, on the template below the question. Despite a target time of 10 minutes, interviews lasted in most cases between 15 and 25 minutes, and two of the interviews took more than 30 minutes. The interviewed are considered as potential customers, and therefore subjects are referred to as customers in this presentation.

Fewer women than men have participated in the survey, which is not conducive for an investigation related to households and electricity consumption. However, there is uncertainty whether it can have a significant impact on the results obtained. The typical household consisted of an adult couple, with one or two children. The only information given before the customer interview has been that it would be made with house-owners in which the questions would be about energy and electricity consumption within the household. In several cases this has led to the event of the woman given over the phone to her husband, in case the husband was at home. No particular thought has been devoted to this problem in the report other than of the men, hopefully, have represented their households account given to their partners.

Results from interviews

The customers consisted of two owners of terraced houses, sixteen house-owners, two house-owners with a tenant, and one house-tenant. The tenant was not questioned on information regarding details such as electricity consumption or electricity agreement, since the monthly rent was fixed and it was the landlord holding the agreement and paying the electricity bill. The location of customers was mixed; both rural and urban areas were included, and from the middle part of Sweden to the very north. Most customers, about 70 percent, were from rural areas or small towns in the middle of the country. Basic information on the interviewed is presented in *Figure 6.1*, and three women and seventeen men were included in the survey.

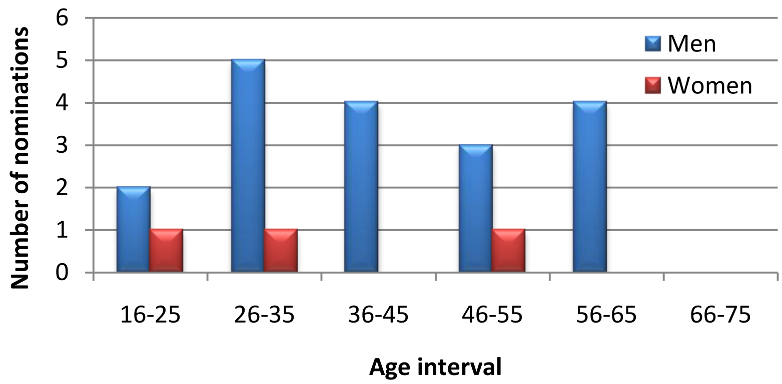
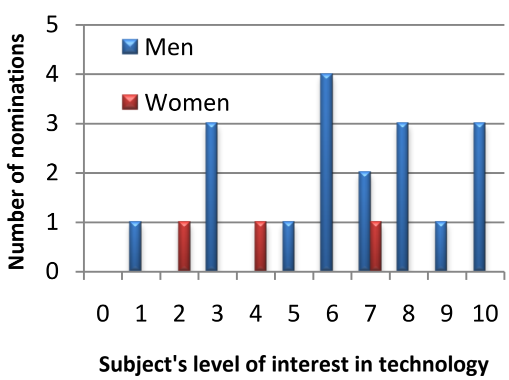


Figure 6.1 – Age interval also showing number of men and women respectively included in the survey (21/21 customers included)

One of the questions involved the customer's own opinion about his or her general interest in technology, where the finding shows that the majority seemed to have an interest of 6 or higher, on a scale from 0 to 10. The mean of responses for all customers was 6.2, which for men was 6.6 and for women 4.3. The answers were as follows.



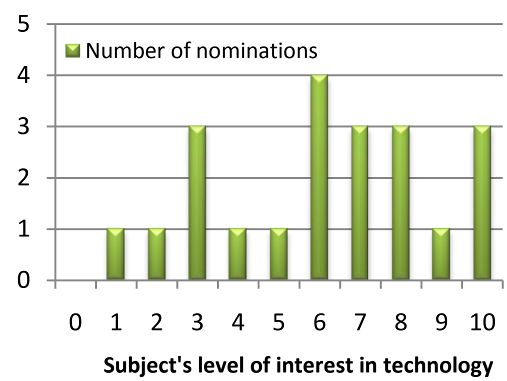


Figure 6.2 – Customers given opinion of interest in technology (21/21)

Regarding information on the annual electricity consumption, customers gave an estimated value or looked up the designated value of the last invoice. The result shows that 70 percent of the customers gave a value higher than 15 000 kWh. Two customers, of the total of 21, gave figures below 10 000 kWh. It turned out that one of those two house-owners had district heating connected to the house, and the other took care of heating entirely by a newly installed pellet boiler. The customer with over 30 000 kWh, was one of the two landlords interviewed. The consumption was for two households including a total of ten people. Interestingly, the heating system for the house including two households consisted of a large wood boiler, and the house-owner expressed a considerable desire of bringing down the electricity consumption. The house-owner has for a long time wondered where all the electricity goes to.

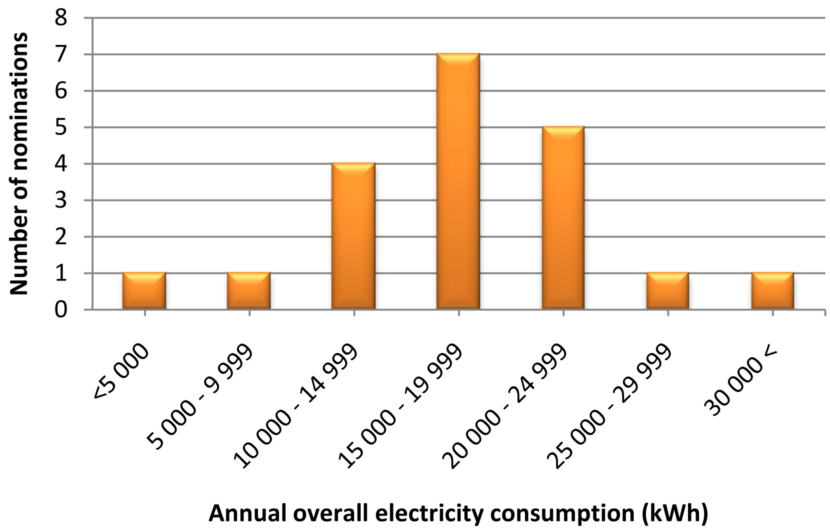


Figure 6.3 – Figures on the annual overall electricity consumption for the customers (20/21)

The type of agreement used was asked to the customers during the interview, where a slight majority had some form of fixed agreement. Distribution of the various forms of agreement is shown in *Figure 6.4*.

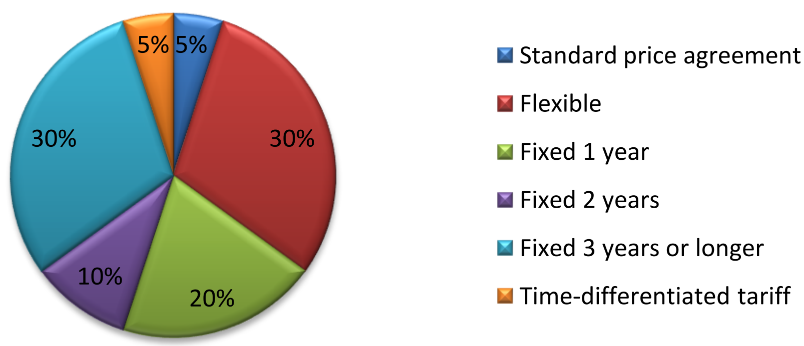


Figure 6.4 – Price agreements for the customers (20/21)

The customers were asked if their electricity companies offered web services to keep track of the electricity consumption. As follow-up, they were also asked if they were using the service. As shown below, 20 percent of the customers were using the service. A good part, 65 percent, did not know of any web service of that kind provided by their electricity company.

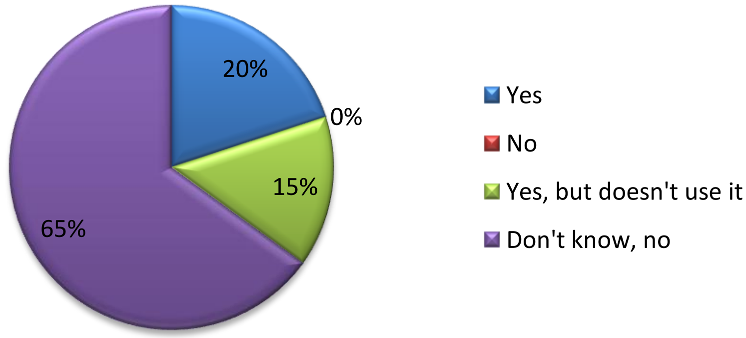


Figure 6.5 – Answers to questions of electricity company offering a web service, and if the house-owner is using the service (20/21)

When asked about agreements and web services, many of the customers also gave their view on their electricity company. None of those interviewed expressed any specific dissatisfaction with the measurement and reporting of electricity consumption by the electricity company. In some cases, however, customers expressed a desire that the invoices should be easier to comprehend. Furthermore, several house-owners, mostly in the age group of 46-55 and 56-65, expressed a feeling that the step to monthly reporting has made it easier to keep an eye on the consumption.

All customers were asked if they were in control of the household's electricity consumption, and had knowledge of individual appliances' impact on the electricity bill. The answers are given below, showing 52 percent thought they were in control and had knowledge, while the remaining 48 percent felt as they did not, or felt that they were uncertain regarding the issue.

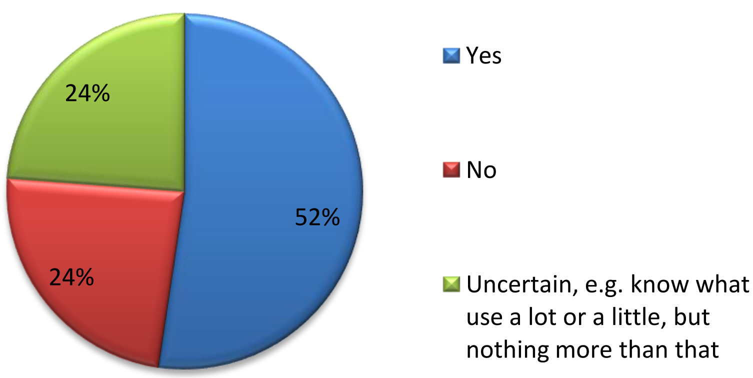


Figure 6.6 – Answers to the question of the house-owner having control of the household's electricity consumption, and know of individual appliances' impact on the electricity bill (21/21)

Regarding the question on interest towards receiving more detailed information of the household's electricity consumption than they are receiving to date (given that the information could help explaining bills further, or perhaps provide a basis for energy saving measures), the findings were that the customers are very interested in such information. For this question, the customers were given a fixed interval for placing their grade of interest. Many of the customers with a high interest-answer explained that they saw opportunities in getting more information. A few of the customers indicating *interested* or *very interested*, though, explained their level with phrases such as “it can never harm” or “it would probably be out of pure curiosity”.

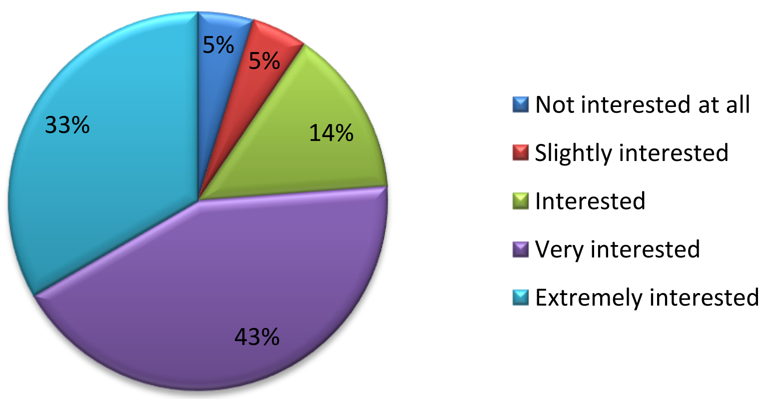


Figure 6.7 – Interest towards receiving more detailed information of the household's electricity consumption (21/21)

When asked if there were any fixed electrical installations in the house (for example heating system, appliances, or lights), the customers were also asked whether they were interested in knowing the impact of these on the electricity bill and the overall electricity consumption. Most of the customers, 76 percent, wanted to get information on this, 10 percent felt uncertain, while 14 percent did not see any reason why or did not think they would have time to ponder such things. Many of the customers answering *yes*, mentioned especially equipment such as heat pump and radiator. Other desired appliances especially mentioned were refrigerator and freezer.

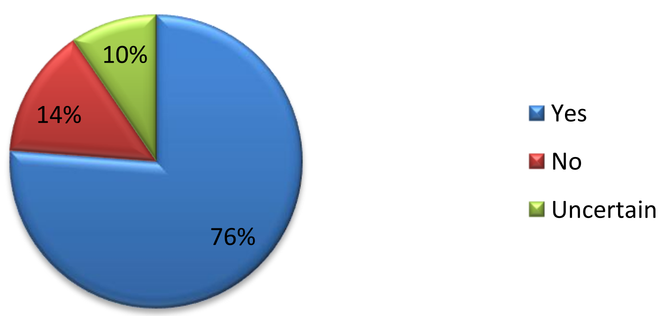


Figure 6.8 – Answers to question if there were any fixed electrical installations in the house, and if the customers were interested in knowing the impact of these on the electricity bill and the overall electricity consumption (21/21)

It was further asked how useful it would be for the customer to receive detailed information down to room-basis or even appliance-specific, where consumption is measured very precisely at secondary level and continuously, with various time intervals. A fixed interval was used for this question also. Only 9 percent of the customers gave an answer indicating they did not see any obvious use of getting this kind of information, one of them mentioning “it would be fun to watch though”. Plenty of uses were described by the house-owners including better track on the electricity consumption for heating system and major appliances, but also the use of electronics such as computers within the household. A few house-owners expressed specific interest for the ability of showing the rest of the house-hold, mainly the children, the electricity cost for their respective activities. Another customer said that he would like to know how much the heating cost was for a storage space that was used and needed heating.

Apart from possible savings, one of the customers thought that it could be easier to sell the house, if it would be possible to show real figures on the energy use instead of estimated values that are not at all accurate. This was also indicated by another customer, who recently moved into a new house, who was quite sure that people generally want to know what the operating expenses are for the house they intend to buy.

A question was asked to the two landlords regarding the interest of having the possibility for specific electricity metering of their tenants. Both landlords expressed a significant desire of having separate metering for the tenant. The thoughts on this were that it would be useful of knowing the figures, both for the landlord and the tenant. It was mentioned by one of the landlords that living as a tenant with fixed rental did not provide incentives for re-ducing electricity costs. The other landlord pointed out the fact that, due to regulations, he was not allowed to provide the tenant with electricity bills in any way. With specific information though, both landlords thought it would be a good incentive for the tenants reducing the electricity consumption.

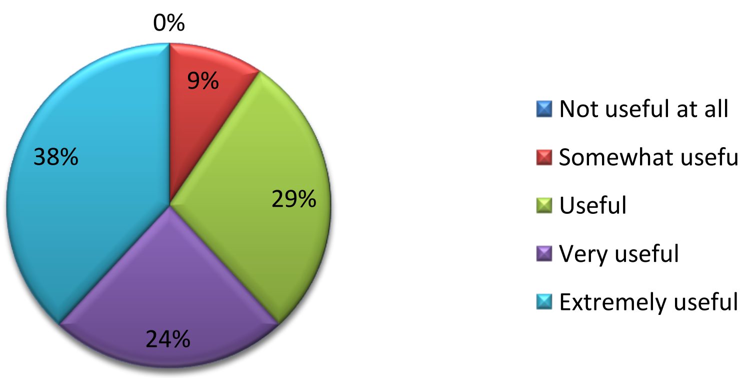


Figure 6.9 - Answers to the question on how useful it would be for you to get detailed information (building, room, appliance), where consumption is measured very precisely (secondary level) and continuing over various time intervals (21/21)

The findings on in what way customers wanted to receive more detailed information about the household appliances’ electricity consumption, is presented in *Figure 6.10*. This was asked to all customers despite level of interest, and with fixed answers to choose from. Close to half of the customers thought it would be easiest to get the information via computer with internet connection, while about 24 percent would prefer a combined solution with a separate display (for example in the kitchen or hall) together with more details received using a computer. The result shows that about 24 percent also favored the solution with a display, and about 5 percent on a combined solution with computer and cell phone. Clearly, most of the customers included in the study would prefer a solution involving computer and separate display.

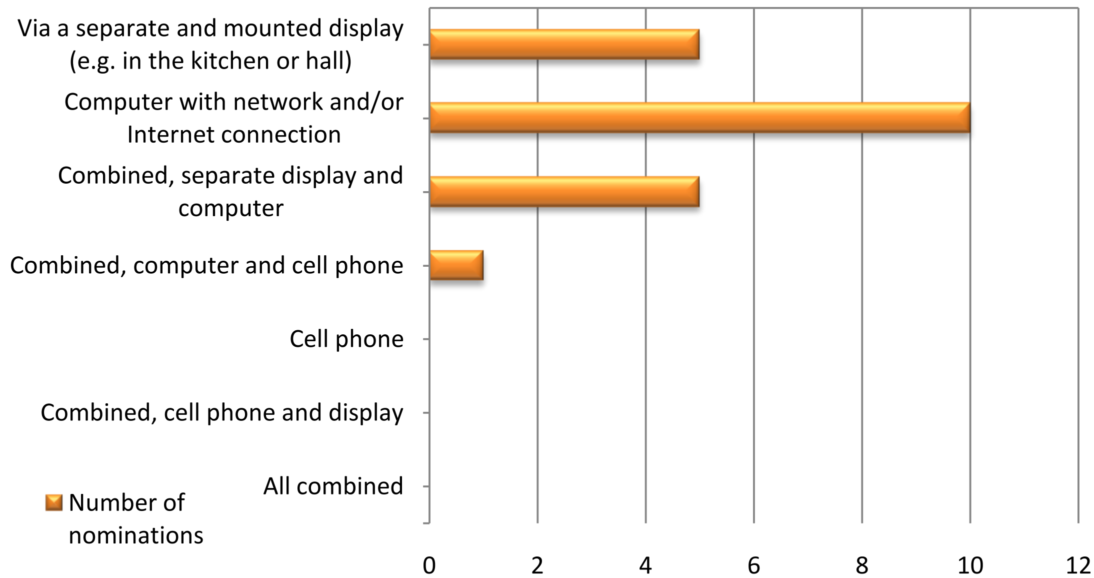


Figure 6.10 – Answers to the question, despite level of interest, in what way the customer would like to receive more detailed information about the household's appliances' electricity consumption (21/21)

The question of investigating the willingness to pay for a product, thought of as providing the customer with some kind of disaggregated feedback, was asked to the customers. More specifically, the customers were asked *if they would pay for a product, continuously providing detailed and comprehensive information on the household's past and current consumption, which had the defined purpose of helping the household to reduce costs and energy use*. The findings show that 67 percent gave an answer indicating they would buy such a product, while 9 percent had no interest in buying such a product, and 24 percent were uncertain. The 9 percent, or the two customers, answering *no* include the tenant, who on the other hand thought he might think otherwise if becoming a house-owner in the future. Several customers, despite a final answer given, expressed thoughts on that they were not sure in what way they could actually reduce the electricity consumption, for example one of the customers thought of buying more effective lamps instead of the cheapest, but had not thought of anything in particular except for that. There were many answers, though, indicating that they believe they are using a lot energy because of wasteful behavior. Customers answering *uncertain* includes one customer who simply were uncertain, but also four interested customers that were careful pointing out that they would expect a product pay off time of no longer than one or a couple of years. They would not buy such a product just to give it a try and to see how much energy and cost savings it could make. The results are given in *Figure 6.11*.

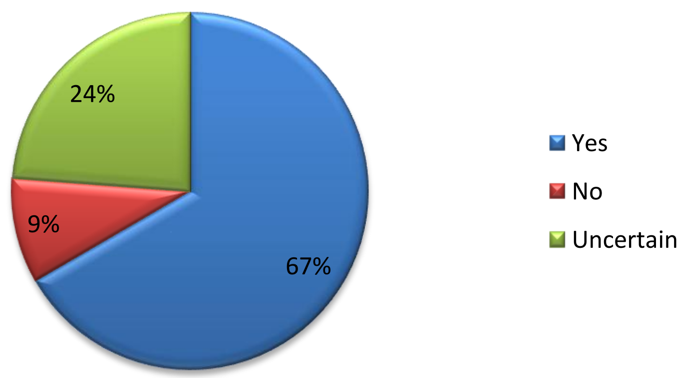


Figure 6.11 – Customers' answers when questioned if they would pay for a product, continuously providing detailed information on the household's past and current comprehensive consumption, which had the defined purpose of helping the household to reduce costs and energy use (21/21)

As a follow-up, an estimated price limit for the investment cost was given to the customers. Many of the customers expressed difficulties in giving figures on a specific amount of money in valuing such a product. Some answers were also given without much thought. A good part of the customers, 38 percent, gave an answer assuming they would pay about 1 000 SEK, some explaining that they would probably buy the product in plain hope of saving as much as possible. One of the customers explained doubts about saving anything at all, but that he would probably pay up to 2 000 SEK for such a product anyway to give it a try and by pure interest of monitoring the household's devices. Three customers could not give any specific answer on estimated price limit; these customers were also included in the category of *uncertain* in the previous question regarding willingness to pay for a product. One of the customers conducted a quick calculation when asked, assuming a figure of 5 percent annual savings would be possible on receiving good information, leading to an investment cost of 3 000 SEK would pay off within at least three years. A few of the customers would consider paying for such a product with a subscription, for example monthly or annual fee, where they would consider paying more if price of electricity gets higher. The statements on estimated price limits gave the result presented in *Figure 6.12*.

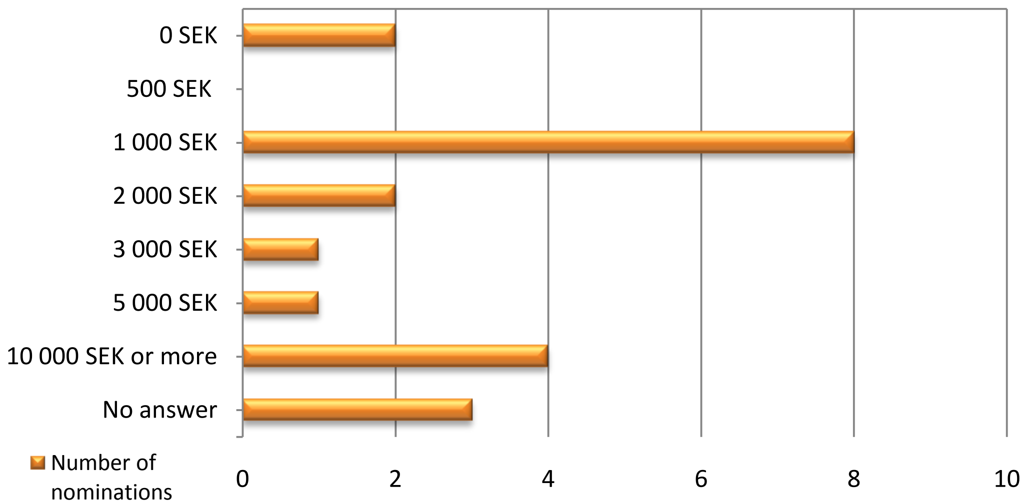


Figure 6.12 – Customers' estimated price limit for an investment cost (21/21)

As a final question, customers were asked if they owned any metering equipment able to measure the electricity consumption for appliances within the house, for example a plug-in electricity meter. Only one of the customers had made measurements on electrical appliances within the house by pure curiosity, having two plug-in meters to keep track on the consumption for TV and entertainments, planning to make measurements in the laundry room as well. This customer, already owning two plug-in meters, had expressed particular interest in a product providing more detailed and comprehensive consumption information.

There were also questions asked regarding computer and Internet use, which all of the customers were using, finding about 86 percent of the customer was using the computer and Internet every day. There were great varieties in the time of use; with a minimum of one hour, up to constantly having the devices on and use was a come and go procedure. About 71 percent had several computers in the house using the Internet. The same number of customers was using a wireless internet connection within the house, although not the same customers having several computers.

7. Discussion

This chapter provides a discussion of the results given in the previous section. It begins by discussing the conditions that exist on the basis of the electricity metering that is currently performed in households. This is followed by the discussion of the results found on how to provide energy feedback for households, which is followed by a discussion of results given on the customer survey.

7.1 Meters in households

As described in Chapter 5, AMR deployment occurs over large parts of the world, where Europe and the US can be considered having the best progress with its expansion. Smart grid and smart meters are two interesting technology implementations in the electrical distribution system. These techniques involve a variety of future possibilities, which can be debated more or less forever. The closest at hand for many countries, such as Sweden, is to discuss the needs and opportunities to go down to hourly readings and time-of-use rates for residential customers. This is expected to reduce peak load, which, among other things, would mean that the energy balance becomes more manageable and also to bring lower prices. The main objective with load control would be to avoid constructions of new power plants, despite a growing number of electricity consumers. Apart from remote meter reading, AMR and AMM systems are intended to provide customers with meaningful consumption and tariff information, have control of the supply and send control systems for smart homes. The smart home is an ambiguous concept, but it is possible that time-of-use tariffs and load control may be used in such houses. How this is supposed to work in practice has not been studied in detail in this report. But there are still several key questions to ask. Should all houses be equipped with time-of-use tariffs and load control, or only some? Should it be compulsory or voluntary? Is it possible to combine load control of specific appliances with measurements in order to provide house-owners real-time energy feedback? In all cases, as was mentioned in Chapter 3, it is very clear that one can not only rely on new constructions in order to reduce energy use in houses, since the new constructions account for only 1 percent of the total building stock per year. Will there be smart homes with a 1 percent annual increase with new construction, or will the existing buildings be provided with smart home features? If smart houses become a reality, DEF should maybe be designed to be compatible with smart meters and smart grid, at least in terms of receiving information given by the electricity company. This means that the DEF product, even if it is intended to serve households, may be appropriate to advertise the DSOs and electric utilities, rather than to the end consumers. The original purpose of DEF is not, however, for allowing DSOs and electricity companies to use load control, but rather to facilitate energy savings within houses.

The electricity measurement market in Sweden is currently regulated, and the major electricity companies have a monopoly on the measurement of its customers. More specifically, the regulation is for metering, calculation and reporting of transmitted electricity to the electricity company. There are voices raised to deregulate the electricity measurement market, but the probability for this, or when it might occur, is unclear. It is likely that electricity meter reading, which so far has been the activity for DSOs and electricity companies in order to run their business, mostly have been in order to provide accurate bills to their customers. This can be expected to change, though, mainly because of the opportunities that the deployment of smart grid and smart metering is intended to provide. Several electricity companies offer online services for their customers, where customer-specific information is provided, for example keeping track of the consumption on a daily basis. Customers can also access comparative statistics and plenty of general guidelines and suggestions on how to reduce energy use. Still, how far an electricity supplier is willing to go and if it is the best party to make it easier for customers to save energy are plausible concerns for any house-owner. The best technologies for obtaining direct feedback are likely to involve in-house solutions. A subject that has not yet been considered is the issue of privacy. Are ordinary house-owners and electricity customers even willing to provide details, such as use of appliances, which may be comprehensive for the house electronics? The information will be sent long distance to reach the electricity company, who then will choose what the customer should take note of.

In Sweden and by many DSOs, the measurements are made per hour, and meter data are sent daily. Several DSOs have planned for providing measurements and reporting per hour for residential customers, but it is uncertain when this can happen and whether this is a priority for DSOs as long as the legal requirement is set on a monthly basis.

7.2 Providing energy feedback for households

As already mentioned, it is likely that electricity meter reading, mostly have been in order to provide electricity consumers with accurate bills, rather than to provide constructive feedback to conserve energy use. Through technology development, however, opportunities are provided to reconnect energy use impact on the owner's economy and welfare. There is considerable activity going on within the market of electricity metering and feedback, which in addition to where multinational electricity companies operate, also include players such as Google and Microsoft, who entered only about a year ago.

The shift towards monthly reading and billing was a big step towards better feedback of electricity consumption for Swedish households. However, according to studies carried out in the field and as exemplified in this report, there are good opportunities for greater savings through faster feedback. In this report, examples have been given of products providing households with feedback on electricity consumption. An obvious advantage with direct display, which shows immediate changes when appliances are switched on or off, is that they are easy to install. Since the equipment can use a pulse meter that takes advantage of the accuracy of the existing electricity meter belonging to the DSO, or by using a clamp, there is no electrician needed to install the product. A direct display is therefore an inexpensive solution for providing electricity feedback, which paves the way for it to pay off quickly if it is successful in conveying useful information to the household, so that savings can be made. If a direct display costs 1 000 SEK, and could provide a 5 – 15 percent annual saving according to the research by Darby, this would suggest that for an average apartment with 3 000 kWh of electricity consumption, annual savings will be 150 – 450 SEK[8], providing a pay-off time somewhere in between 2 and 7 years. According to Darby, the norm is 10 percent savings, which would give a pay-off time of about 3 years.

[8] Based on an electricity price of 1 SEK / kWh.

There are, however, obvious functional limitations when only measuring the overall electricity consumption for a household, even if a very short time interval is chosen. For a specific time, get an idea of and to learn how much electricity certain appliances consume for a specific activity performed, for example in the kitchen using the microwave at full power for two minutes, is a very feasible task for a direct display. The reason for using direct display and energy feedback would be to affect human behavior and create conservation strategies. When using a feedback device it is also possible to get a view or an alert if an error occurs with electrically powered devices. If it is appliance-specific, though, it would make it possible to clearly see how the appliance-specific electricity and power consumption is changing over time, making it possible to provide information and alerts on errors for example for a heat pump. As described previously, it may be difficult and cumbersome for house-owners with plenty of connected appliances, to troubleshoot in the house using a direct display. A direct display equipped with historical feedback will be able to show successes, or failures in reducing energy use. This becomes most evident in households where electricity consumption is only made up of household-specific electricity, for example an apartment. As shown in the background chapter, the household electricity can be approximated to only 25 kWh/m^2 of a total of 210 kWh/m^2 in existing houses, which makes it equivalent to about 12 percent of the overall electricity consumption in houses using direct electrical heating. Feedback on the hot water and additional electricity consumption should therefore have the potential to provide greater savings for a household, depending on the amount of energy that can be considered to be affected by receiving any kind of energy feedback. Primarily, the so called activity-related energy use is submitted. Houses where all the heating is provided by electricity are well suited for improved electricity feedback. Providing electricity feedback for water use, such as water heated for showering, would probably be difficult to receive instantly. As soon as electricity is used for heating the water again, however, this specific information becomes available.

If we consider only household electricity, the cost for it should usually be more for a house-owner than for an apartment-owner. The average consumption of household electricity for Swedish houses are 6 000 kWh, which would make a feedback product with potential savings of between 5 and 15 percent resulting in annual savings of 300-900 kWh. Assuming that these savings are possible, a house-owner should be able to cope with a higher investment cost than what an apartment owner can. DEF may, however, be equipped with more uses than only providing direct feedback on various energy-consuming devices of the household electricity. Possible other issues are to detect and identify incorrect equipment, provide decision support for replacement of appliances, as well as providing a good basis for the decision of a change of heating system from direct electrical. DEF would create opportunities of accurate measured data, rather than estimated data, which could provide information on how much the cost of 1 degree Celsius decrease or increase of indoor temperature would be (which of course also depends on outdoor temperature), and provide some information on the hot water use as the water heater can be covered. The effect of large building measures, such as a heat pump investment, will of course be visible through the indirect feedback that the house-owner is already accessing. On the other hand and as already mentioned, it will become easier to create a decision basis for an investment if house-owners know in advance how much electricity is being used for heating. This can only be estimated if it is not being separately measured. Furthermore, although there are no specific detailed data required for the EPC that DEF would possibly make available, more accurate information available should be of interest for people intending to buy a house. In Sweden, about 80 000 houses are sold every year. Most buyers of houses are couples, giving that there are 160 000 people who every year are interested in detailed information about energy use for the house they are considering buying.

Although this report is not intended to develop the specific technology to achieve DEF, it can still be stated that DEF should have some kind of direct feedback. This is because indirect feedback does not have the same amount of saving potential. To equip a DEF product with some kind of command and control technology would probably provide larger savings, such as regulating indoor temperature in different rooms. Such a product would then be developed to meet a different need than the DEF is originally intended for. If this still becomes relevant in the nearest future, more material should be collected and further customer surveys carried out.

DEF is intended to use appliance-specific or group-specific feedback. With DEF it would be possible to obtain separate electricity consumption information, which might be suitable for houses that are multi-family houses with shared electricity. It would also be useful to get the tenants engaged in behaving in a more energy efficient way. An individual debiting of the tenant's electricity consumption would provide an incentive for the tenant to be energy efficient. The specific rules or legislation for doing that have not been investigated in detail in this report, other than that metering, calculation and reporting of transmitted electricity to the electricity company for debiting is regulated for DSOs.

7.3 House-owner’s interest in Disaggregated Energy Feedback

Of the conducted customer survey it was found that 80 percent of the house-owners are not using any web service to monitor the overall electricity consumption, even though 86 percent are using a computer and internet every day. Most did not even know if there were such services offered by the electricity company or not. After verification of the proportion of the surveyed customers who actually have access to such services, it turns out to be 65 percent. The remaining 35 percent do not have current access to such web service given by the electric company. The reason why nearly half of the customers do not use the available online service, can be either that the electricity company has not been successful in informing them about the service, or that customers have not had any interest for it at all – not even to absorb information about the services available. Only one of the interviewed house-owners had plug-in meter equipment at home, for examining the electricity consumption for different appliances. Could it possibly be that house-owners are not interested in reducing the electricity consumption and costs, or thinking that being provided with more information would not help? Well, the customer survey for this study indicates something quite different. There are no doubts that the house-owners want to receive more information on their electricity consumption. The information should help explaining bills and provide a basis for energy saving measures. The reasons for the interest were, however, differentiated. Some customers felt that they needed help, while others felt that there was no harm in accessing more information. This provides no possibility of drawing clear conclusions about *how* interested customers actually are in receiving more detailed track of their electricity consumption, but merely that they are not uninterested.

Results from the customer survey suggest that electricity information on fixed installations is a desired feature. As shown in *Figure 6.8*, there were 76 percent of the customers answering that they would like to get electricity consumption data on fixed installations, including heat pump, radiators, and also refrigerator and freezer. This information is not available in detail on the invoices, or typically cannot be measured using a plug-in meter. Using direct feedback, using a pulse meter with display, could make the appliance-specific electricity use instantly visible when switching on or off (depending on device specific energy use patterns). With DEF, the switching on or off would not be needed though, and the presentation of the appliance-specific or group-specific information would be simple. According to results presented in *Figure 6.9* and *Figure 6.10*, the majority of house-owners would consider a solution that DEF refers to as something very valuable to have in the house, preferring a solution including a separate mounted display and/or using an existing computer in the house.

Since a considerable majority of the customers said that they would be willing to pay for this kind of product, it seems very likely that house-owners are interested in DEF. The reasons for being interested seem to differ a lot, considering the responses given on the price limit question. Despite the fact that many of the customers had problems giving specific figures, and some of them gave figures without much thoughtfulness at all, it is reasonable to assume that some of the house-owners would buy such a product. Some of the customers would buy such a product merely to get a picture of the electricity consumption, without being sure of what savings can be made. This group of house-owners would fall into the 1 000 SEK investment category. Equally many customers stated that they would pay more, several expressing optimistic thoughts and saw lots of saving potential. Three out of the four customers pointing out that they would expect a short pay off time, were not prepared to give any specific figures on an investment cost. A DEF product should of course be designed so that it will pay off as quickly as possible, but it is likely to require professional installation. It would be difficult for a product that requires professional installation costs to pay off in just one year. It is also conceivable to design the product with any kind of subscription, as some of the customers voluntarily suggested. A DEF product that is inserted with fixed installation into a house is originally meant to increase the value of the house in several aspects.

8. Conclusions

The future view of Disaggregated Electricity Feedback

In making energy use visible instead of hidden and aggregated there are many possibilities where many parties can be involved in achieving a change. The final responsibility will remain with the households themselves. They are the ones who need to reduce the energy use and they must take the initiative. Monthly bills give possibilities of having an idea of the impact of large construction-specific measures, but they are not good enough to provide feedback on electricity consumption in houses. Furthermore, it is possible to learn something by calculating the electricity consumption of individual appliances based on its labeling and connected time, or perhaps by counting the LED pulses on a standard meter. Given the number of appliances in many houses, these methods are too cumbersome and time consuming for most people. Appliances that vary their energy use are even more difficult to calculate. Using a direct display, showing instant overall electricity consumption, is one possibility of getting a picture of the energy use by different activities. Using DEF, appliances with variable energy use will not disturb the presentation of the feedback, appliance-specific or group-specific consumption information will be given that would be particularly suitable in houses using a lot of electricity.

Advanced meter deployment occurs in many countries of the world, especially in Europe and the US. Variations of AMR meters exist, where countries around the world have different conditions, needs and desires for implementing different types of technology. Member countries of the EU follow the directives specified by the EU Commission. In Sweden, the households are provided with information on their overall electricity consumption at least once a month in combination with billing. In most cases, the measurement is made per hour, and meter data is collected daily. Households wanting to take part of meter data more frequently, can use web services if available, or read and follow the meter display on their own. The technical life time of the AMR meters in Sweden is uncertain, since periodic inspections will determine how long the installed meters will be in use. Some DSOs in Sweden are already in position of providing measurement and reporting per hour for many of the residential customers, but it is uncertain when this might happen in full scale. The legal requirement is today set on a monthly basis.

DEF should be equipped with direct feedback. This is because indirect feedback does not have the same degree of saving potential. The average consumption of household electricity for Swedish houses are 6 000 kWh, which would have the potential for annual savings of 300 – 900 kWh using direct feedback. The building stock in Sweden consists of 1.74 million houses, which would make the potential annual savings up to 1.57 GWh. DEF can provide more detailed energy feedback, presenting group-specific or appliance-specific consumption data, than a direct display showing only overall consumption.

DEF can provide several potential benefits for a house-owner;

- Provide direct feedback on various energy-consuming devices of the household electricity

- Detect and identify incorrect equipment
- Provide decision support for replacement of appliances
- Provide an accurate basis for the decision of a change of heating system from direct electrical
- Provide accurate information of the electricity consumption for the house, which should be of interest for people intending to buy the house
- Provide separated electricity consumption information for multi-family houses with shared electricity
- Create incentives for house-tenants to behave in a more energy efficient way

The customer survey, conducted in January 2010, shows that there is great interest in what the DEF can offer house-owners. The design and creation of a DEF product should be made so that it will pay off as quickly as possible, but it is likely to require professional installation.

There are reasons to further investigate whether DEF can be useful for electricity companies as well as house-owners, who want to offer individual customers enhanced services. Time-of-use tariffs and load control are possible future implementations by the electricity companies, which are possible with hourly metering, in which DEF can take an important role in conveying information to the household. But it is also conceivable that DEF can be supplemented by equipment to receive more advanced control signals.

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Appendices

Appendix A

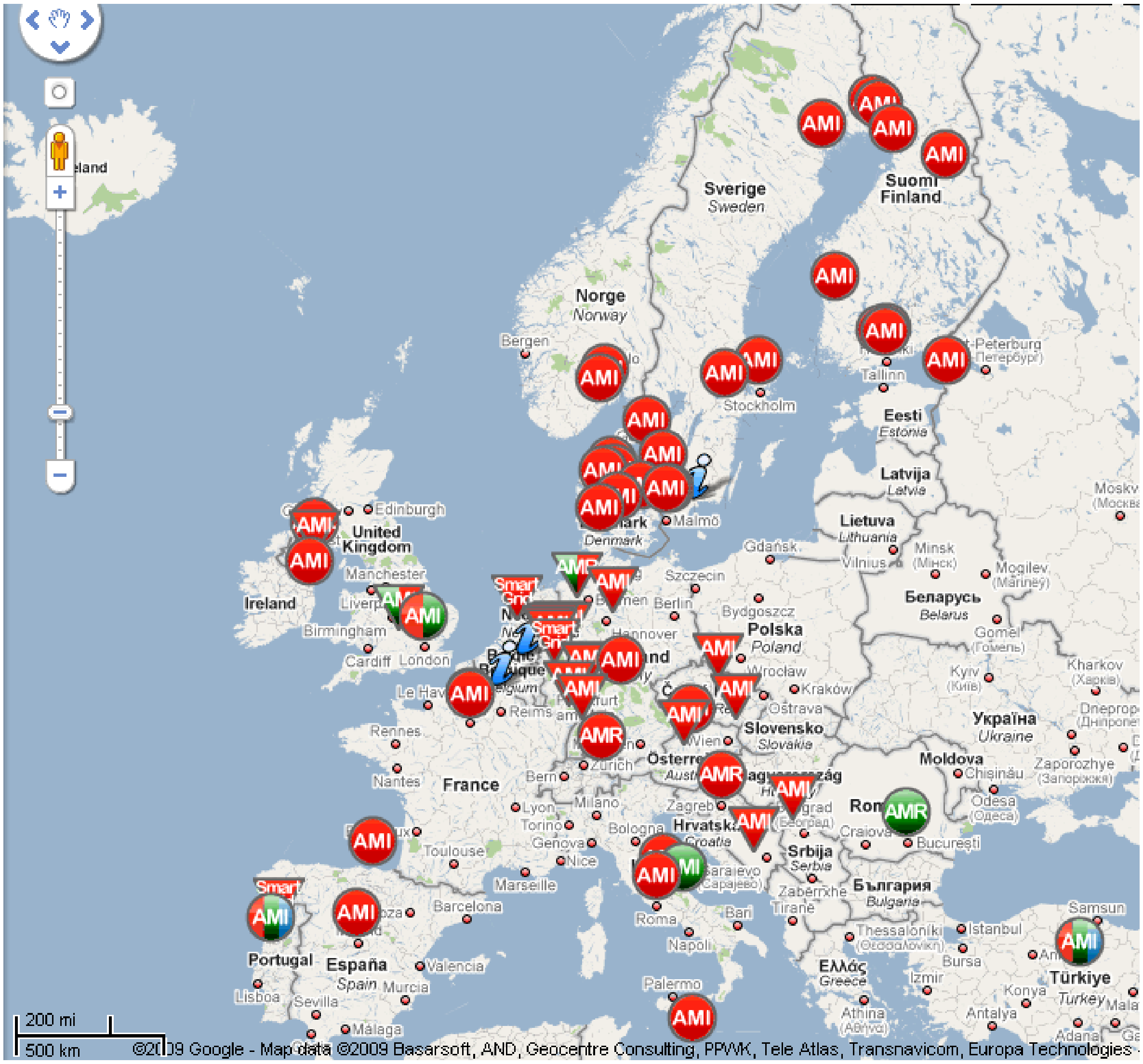

Figure A.1 – Advanced metering roll out in Europe (Meterpedia 2009)

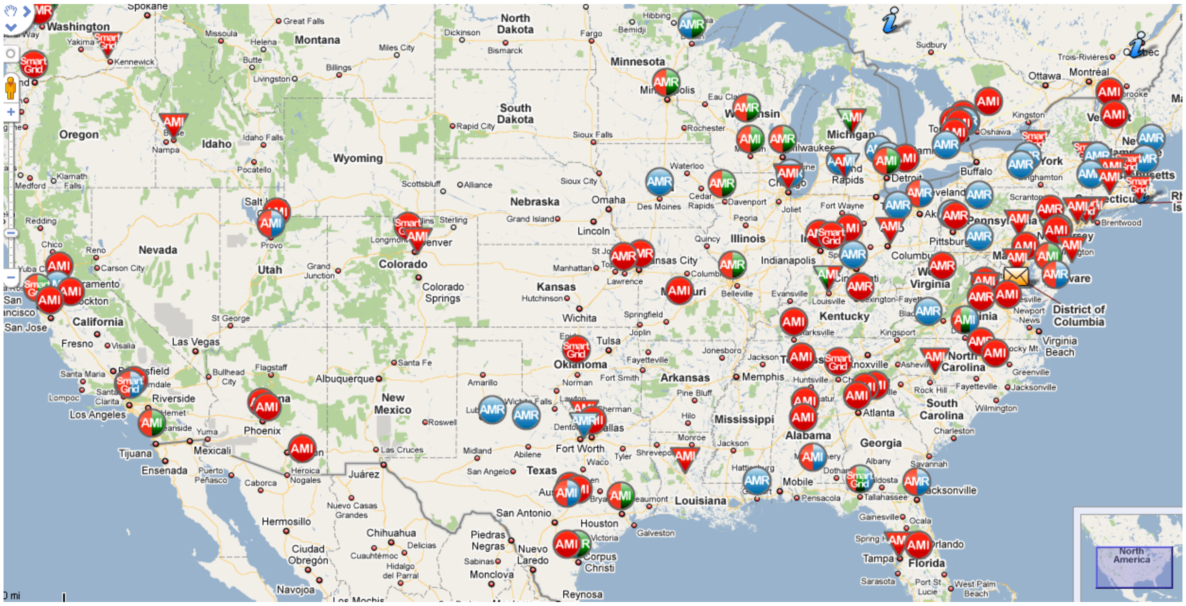

Figure A.2 – Advanced meter rollout in the US (Meterpedia 2009)

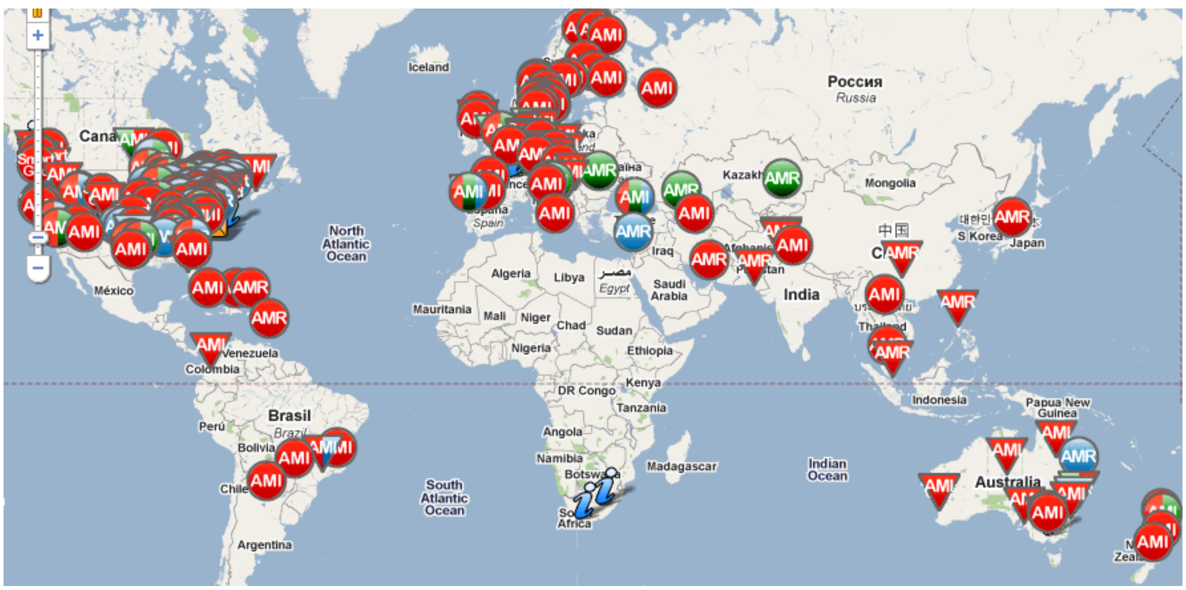

Figure A.3 – Advanced meter rollout in the world (Meterpedia 2009)

Appendix B

SAMS, SvenskA MätSamarbetet,
Members of the consortium are:

- Ale Elförening;
- Bergs Tingslags Elektriska AB
- Bodens Energi Nät AB
- Borås Energi Nät AB
- Energiverken i Halmstad Elnät AB
- Eskilstuna Energi & Miljö AB
- Göteborg Energi AB
- Götene Elförening
- Habo Kraft AB
- Härjeåns Nät AB
- Härnösand Elnät AB
- Härryda Energi AB
- Jämtkraft Elnät AB
- Jönköping Energi Nät AB
- Kungälv Energi AB
- Lerum Energi AB
- Ljusdal Elnät AB
- Luleå Energi Elnät AB
- Mariestad Töreboda Energi AB
- Mälarenergi AB
- Mölndal Energi AB
- SEVAB Nät AB
- Sundsvall Energi Elnät AB
- Söderhamn Elnät AB
- Tekniska Verken i Linköping AB
- Telge Energi Nät AB
- Tidaholms Energi AB
- Umeå Energi Elnät AB
- Vaggeryds Elverk AB
- Varberg Energi AB
- Varbergsortens Elkraft
- Västerviks Kraft Elnät AB
- Ystad Energi AB

Appendix C

(In Swedish only)

Intervjufrågor husägare
Frågor (inledningsvis förklara att det är anonymt)

1.) Kön?
    a) Man
    b) Kvinna

2.) Ålder?
    ____

3.) Antal boende i ditt hus?
    ____

4.) Har du någon ungefärlig uppgift om hur många kWh el resp. kronor som hushållet använder per år?
    ______________ kWh   _____________ kr

    Om nej,
    sparar du fakturor, och skulle du vilja delge din årsförbrukning utifrån dessa?
    ____

5.) Vilken typ av elavtal har du? Fast eller rörligt?
    ____

6.) Vem är det i hushållet som betalar elräkningen?
    a) Den intervjuade
    b) Någon annan
    ____
    ____

7.) Tycker du att du kan förstå din elförbrukning utifrån fakturan?
    a) Ja
    b) Nej
    c) Osäker

    Om b)
    Vad tycker du saknas i den information som du får från elbolaget? Vilken information skulle du vilja ha om din elförbrukning?
    ____
    ____
    ____

8.) Vet du om ditt elbolag erbjuder dig en webbtjänst för att följa elförbrukningen, t.ex. ”Mina Sidor”, och använder du denna någonting?
   a) Ja
   b) Nej
   c) Ja, men använder inte
   d) Vet ej (nej)

   ____

   ____

9.) Anser du att du har kontroll över hushållets elförbrukning, och har du koll på enskilda apparaters inverkan på elräkningen?
   a) Ja
   b) Nej
   c) Osäker

   ____

   ____

10.) Hur pass intresserad är du av att få mer ingående information över ditt hushålls elförbrukning (om denna information bl.a. skulle kunna förklara din elräkning och ge förslag på besparingsåtgärder m.m.)? (på en skala 1-5, där 1=Helt ointresserad, 3=Intresserad, 5=Extremt intresserad)

   1 2 3 4 5

   ____

   ____

11.) Finns det fasta installationer i hushållet som drivs med el (t.ex. värmesystem, vitvaror eller lampor), där du skulle vilja veta hur mycket dessa påverkar elräkningen?
   a) Ja
   b) Nej
   c) Osäker

   ____

   ____

12.) Hur värdefullt skulle det vara för dig att få detaljerad information (per apparat, rum, byggnad) där förbrukning kan mätas mycket exakt (sekund nivå) över olika tidsintervall (dagar, veckor, månader) fortlöpande? (skala 1-5, 1=Inte alls värdefullt, 3=Värdefullt, 5=Extremt värdefullt)

   1 2 3 4 5

   ____

   ____

13.) Har du bredband och dator i hushållet?
   a) Ja
   b) Nej

Om a)
Hur ofta använder du datorn och internet?
1) Varje dag
2) Några gånger i veckan
3) Minst en gång i veckan
4) Sällan

Om 1 eller 2)
Hur lång tid skulle du uppskatta att datorn vanligtvis är påslagen *då du eller någon annan i hushållet är hemma*? (Intervall 0-1h, 1-2h, 2-5h, 5-hela tiden)

|________|__________|______________________________|______________________|

0 1 2 3 4 5 6 7 <

14.) Finns det flera datorer i hushållet som använder internet?
a) Ja
b) Nej

Om a)
Används trådlöst internet i hushållet?
1) Ja
2) Nej

15.) Om du kunde få tillgång till mer detaljerad information om dina apparaters elförbrukning än i dagsläget, på vilket sätt skulle du föredra att få den?
a) Via en separat och monterad display (t.ex. i köket eller hallen)
b) Via dator med uppkoppling, kan nås utanför hemmet
c) Via mobiltelefon, kan nås utanför hemmet

16.) Om det fanns en produkt som *kontinuerligt kunde tillhandahålla detaljerad information om hushållets tidigare och nuvarande elförbrukning för att minska kostnader och klimatpåverkan,* skulle du då vara villig att betala pengar för en sådan produkt?
a) Ja
b) Nej
c) Osäker

Om a)

Hur mycket skulle du då vara villig att betala för en sådan produkt? (Kryss sätts i intervall 0-500 kr eller 500-1000 kr o.s.v.)

|__________|___________|__________|_________|__________|__________|_________|__

0 500 1000 2000 3000 4000 5000 <

17.) Har du någon gång undersökt energianvändningen för en apparat (t.ex. TV, dator), med någon sorts energimätare? Varför, eller varför inte? Äger du någon energimätare?

a) Ja
b) Nej

18.) Vilket generellt teknikintresse skulle du uppskatta att du har på en skala mellan 0 och 10? (där 0=Inget teknikintresse alls, 5=Teknikintresserad och 10 =Extremt teknikintresserad)