TAMPEREEN TEKNILLINEN YLIOPISTO
TAMPERE UNIVERSITY OF TECHNOLOGY

VILJAMI VÄLIPIRTTI

DEVELOPMENT OF COMPARISON FEEDBACK FOR PRIVATE CUSTOMERS IN ELECTRICITY CONSUMPTION REPORTING SERVICE

Master of Science Thesis

Examiners: Professor Risto Raiko
Professor Pertti Järventausta

The Examiners and the topic approved in the Faculty of Natural Sciences council meeting on the 9th of April 2014

ABSTRACT

TAMPERE UNIVERSITY OF TECHNOLOGY
Master's Degree Programme in Environmental Engineering and Energy Technology
VÄLIPIRTTI, VILJAMI: Development of Comparison Feedback for Private Customers in Electricity Consumption Reporting Service
Master of Science Thesis, 72 pages, 4 Appendix pages
October 2014
Major: Electrical Energy Engineering
Examiners: Professor Risto Raiko and Professor Pertti Järventausta
Keywords: Comparison data, consumption feedback, consumption reporting service, energy efficiency, household

The purpose of this Thesis is to study and analyze the guidelines on development of comparison feedback on electricity consumption in the online consumption reporting service for private customers of electricity distribution network operator Elenia Oy. With comparison feedback on electricity consumption the consumers can get the view on their levels and timings of own consumption compared to the ones of its comparison group. The meaning of consumption reporting service is the improvement of customer service and the decrease of electricity consumption of private customers. As a basis for a Thesis is the regulation, set in the Energy Efficiency Directive and Energy Efficiency Agreements, for the energy sector on actions aiming to reduce the consumption of their customers.

The materials used in this Thesis defray both international and national publications on providing comparison feedback and reports on the electricity consumption in Finland nowadays and in the future. In addition, reports on utilizing the statistical and computational tools have been capitalized in analyze of consumption and temperature data.

The methods used in this Thesis are based, for factors explaining the level of consumption, on classification and for noticing similar load profiles, on clustering algorithm k-means. In temperature correction, the correlation is tried to be found between the variability of consumption and outdoor temperature of consumption sites. With the linear regression analysis the monthly correction coefficients on temperature correction of consumption are got to be defined. For ensuring the validity of the results on temperature correction, the Student's t-test is utilized.

The most important conclusions are the inaccuracy of present comparison data and the non-correspondence of the current service on changing needs in the electricity consumption among consumers in the future.

The achieved results are the suggestion on new definition of comparison groups, new methods for comparing the consumption, diversification of the service, increase of interactivity and utilization of computational temperature correction in the service.

As a recommendation of actions is the versatile update of the consumption reporting service for the private customers. Firstly, the options of collected data on consumption sites should be modified as compatible as presented in this Thesis and increase the number of collected data in the service. More data transfer is needed between the customer relationship management software and the reporting service for enabling the new service methods. Bringing the clustering method k-means into the operational environment of the service is extremely important. As an extra suggestion the company could consider of updating the load profiles of households, for parts of operations, to be based on consumption measurements.

TIIVISTELMÄ

TAMPEREEN TEKNILLINEN YLIOPISTO
Ympäristö- ja energiatekniikan koulutusohjelma
VÄLIPIRTTI, VILJAMI: Yksityisasiakkaiden vertailupalautteen kehittäminen sähkönkulutuksen raportointipalvelussa
Diplomityö, 72 sivua, 4 liitesivua
Lokakuu 2014
Pääaine: Sähköenergiatekniikka
Tarkastajat: professori Risto Raiko ja professori Pertti Järventausta
Avainsanat: Vertailutieto, kulutuspalaute, energiaraportointipalvelu, energiatehokkuus, kotitalous

Tämän diplomityön tarkoituksena on tutkia ja analysoida suuntaviivat sähkönkulutuksen vertailutietopalautteen kehittämiselle sähköverkkoyhtiö Elenia Oy:n yksityisasiakkaille suunnatussa online-energiaraportointipalvelussa. Sähkönkulutuksen vertailupalautteen avulla kuluttajat saavat käsityksen oman kulutuksensa tasosta ja ajoittumisesta verrattuna oman vertailuryhmänsä vastaaviin. Energiaraportointipalvelun pyrkimyksenä on asiakaspalvelun parantaminen ja yksityisasiakkaiden sähkönkulutuksen pienentäminen. Työn lähtökohtana on energiatehokkuusdirektiivissä ja energiatehokkuussopimuksissa energiasektorille asetetut vaatimukset toimista asiakkaidensa kulutuksen pienentämiseen.

Diplomityössä käytettävät aineistot käsittävät sekä kansainvälisiä että kansallisia tutkimusjulkaisuja vertailupalautteen antamisesta ja raportteja kotitalouksien nykyhetken ja tulevaisuuden sähkönkulutuksesta Suomessa. Lisäksi kulutus- ja lämpötilatietojen analysoinnissa on käytetty avuksi raportteja tilastollisten ja laskennallisten työkalujen hyödyntämisestä.

Työssä käytettävät menetelmät perustuvat sähkönkäyttöpaikkojen kulutuksen suuruutta selittävien tekijöiden osalta ryhmittelyyn ja samanlaisten kulutusprofiilien havaitsemisen osalta klusterointimenetelmä k-meansiin. Lämpötilakorjaamisessa käyttöpaikkojen sähkönkulutuksen sekä ulkolämpötilan vaihtelevuuden välille yritetään löytää korreloituvuutta. Lineaarisen regressioanalyysin avulla saadaan määriteltyä kulutuksen lämpötilakorjaamiseen kuukausittaisia korjauskertoimia. Lämpötilakorjaamisen tuloksien oikeellisuuden varmistamiseksi käytetään hyväksi Studentin t-testiä.

Tärkeimmät johtopäätökset ovat tämänhetkisen kulutusvertailutiedon epätarkkuus ja nykyisen palvelun vastaamattomuus tulevaisuuden muuttuviin tarpeisiin kuluttajien sähkönkulutuksessa.

Saadut tulokset ovat ehdotus palvelussa käytettäväksi uudeksi vertailuryhmien määrittelytavaksi, uudet keinot kulutuksen vertailuun, palvelun monipuolistaminen, palvelun interaktiivisuuden kasvattaminen ja laskennallisen lämpötilakorjaamisen mahdollistaminen palvelussa.

Toimenpidesuosituksina on Elenia Oy:n yksityisasiakkaille suunnatun energiaraportointipalvelun päivittäminen. Ensiksi tulisi asiakkailta kerättäviä käyttöpaikan tietoja muokata ehdotetun mukaiseksi ja niiden määrää kasvattaa palvelussa. Asiakastietojärjestelmän ja palvelun välille tarvitaan enemmän tiedonvaihtoa uusien palvelukeinojen mahdollistamiseksi. Klusterointimentelmä k-meansin saattaminen palvelun toimintaympäristöön on ensiarvoisen tärkeää. Tutkimusta sivuavana ehdotuksena yritys voisi harkita osissa toimintojaan kotitalousasiakkaiden kohdalla käytettävien tyyppikuormituskäyrien päivittämistä tuntimittaustietoihin perustuen.

PREFACE

The thesis was provided by Elenia Oy as a part of SGEM (Smart Grids and Energy Markets) research program. The examiners of the thesis were Professor Risto Raiko and Professor Pertti Järventausta from Tampere University of Technology. The supervisors from Elenia Oy were M.Sc. Markku Kauppinen and M.Sc. Matti Halkilahti.

At first I would like to state my thanks to Markku for very interesting topic as well as help through the Thesis. Thank you Matti, for helping me to get the work started well. I want to thank Risto and Pertti for really good advice and comments.

I would also like to give special thanks to M. Sc. Antti Mutanen for helping in temperature correction and sharing ideas for the Thesis. Also special thanks to researcher Matti Mononen from University of Eastern Finland for getting me familiar with clustering and sharing ideas for better consumption feedback.

Besides, thanks for my parents for the encouragement to do my studies well. Last but definitely not least, thank you Emmi for keeping my head up through most of the studies and the whole Thesis.

Tampere, August 18th, 2014

Viljami Välipirtti

TABLE OF CONTENTS

ABBREVIATIONS

AMR	Automatic Meter Reading
CRM	Customer Relationship Management
DH	District heating
DNO	Distribution Network Operator
DG	Distributed Generation
DR	Demand Response
EC	European Commission
EK	Confederation of Finnish Industries
ET	The Finnish Energy Industries
EEA	European Environment Agency
EED	Energy Efficiency Directive
EIP	Energy Information Platform by eMeter
EU	European Union
GH	Geothermal heating
HP	Heat pump
LUT	Lappeenranta University of Technology
MDMS	Meter Data Management System
NIS	Network Information System
OSF	Official Statistics of Finland
SGEM	Smart Grids and Energy Markets research program
SME	Small and medium-sized enterprises
TEM	Ministry of Employment and Economy
TUT	Tampere University of Technology
UNCED	United Nations Conference on Environment and Development
UNFCCC	United Nations Framework Convention on Climate Change

1 INTRODUCTION

Without energy we would have none of essential day-to-day services without which our society and businesses cannot function. During latest centuries, energy issues have shown a significant role in politics globally. Awakening for greenhouse gases increasing greenhouse effect intensively, fossil fuels not lasting forever and the increase of price of electricity, countries have needed to find out solutions to versatile but challenging energy issues. The European Union (EU) has wanted to create regulations for its member countries in their climate and energy politics by creating a common European energy policy. Need for a common European energy policy is explained as a need to react on challenges in energy sector, reliability of energy delivery and competitiveness of the EU.

The climate and energy package that aims to meet the EU's climate and energy targets was set in 2007. The targets set three key objectives by 2020, from which the most interesting one for this thesis is 20 % energy savings. Highly exposed terms in media in Europe, energy efficiency and energy conservation have been thought to be the most considerable solutions for meeting the target. As electricity is one form of energy, also electricity consumption must become more effective and to be reduced. Not only industrial consumption needs to be reduced but also consumption of private consumers, and they have to be encouraged on more effective use of electricity. This thesis aims to analyze the best ways to offer comparison data on electricity consumption for private consumers with online consumption reporting service of electricity distribution network operator (DNO).

Because the climate and energy package does not address the target directly, the EU managed to set the Energy Efficiency Directive (EED) which is the most important tool in achieving the target. More accurate definition on energy efficiency, the EED and national Energy Efficiency Agreements are dealt in Chapter 2.

As the main target of online energy reporting service of Elenia Oy is to give free-of-charge consumption feedback for its private customers to help them to reduce their use of electricity, it is important to research consumers' consumption behaviors and attributes that affect to electricity consumption. However, psychological reasons on consumption behavior are not included in this thesis. Firstly, private customers of Elenia Oy are meant the ones with a main fuse size of 3x63A or less. Secondly, that group consists of several different sub-groups: mainly households but also farms, leisure-time apartments and business apartments for example. They all have different features on consumption. Mostly consumption of household consumers is dealt in this thesis because they comprise overwhelmingly the biggest part of the group of private customers.

Besides, the consumption of other sub-groups has not been studied much. Factors affecting consumption as well as present and future trends in electricity consumption of private consumers are dealt in Chapter 3.

In Chapter 4 the current online energy reporting service is examined and operation of comparison data in the service is analyzed. At the moment, the service offers consumption data from customers' consumption sites, temperature data and comparison data from customers with similar consumption explaining factors. Consumption data of customers is stored in meter data management system (MDMS) as hourly values of electricity consumption are sent there from automatic meter reading (AMR) devices.

Development of comparison data in the reporting service is dealt in Chapter 5. Also ideas for informing customers on more effective electricity use are presented. Development is based on wills of Elenia personnel through interviews and meetings, results of customer inquiries and feedbacks, various publications and writers own vision. Two methods are presented on how comparison data should be determined. Customers would also like to compare their own consumption between different years. Because temperatures among years are different the idea of temperature correction for the service is presented in Chapter 5 as well.

Ideas on future service development are presented in Chapter 6. For instance, development of smart grids and demand response (DR) set new possibilities for changing trends in electricity use but also challenges towards traditional load profiles and classification of consumers.

Elenia Oy is an electricity distribution company providing electricity network services for over 410 000 customers in Finland. Elenia Oy belongs to Elenia Group together with heat services providing company Elenia Lämpö Oy. Elenia Oy is responsible for operation, maintenance and construction of the distribution networks in over one hundred towns in Kanta-Häme, Päijät-Häme, Pirkanmaa, Central Finland and Southern and Northern Ostrobothnia. During past ten years Elenia Oy has become a pioneer company in electricity network domain in Finland by, for example, obtaining a set-up of large-scale automated meter reading and starting a wide scale cabling in rural area as a first company in Finland.

Some researches about customers' electricity consumption and customers' needs for consumption feedback have been done earlier. Adato Energia Oy published in 2013 a research on electricity use of households in Finland in 2011. (Adato Energia Oy 2013). Motiva Oy did a survey in 2009 about feedback on consumption data and energy saving tips (Motiva Oy 2009a). Corinna Fischer has published a report about feedback on households' electricity consumption (Fischer 2008). Researcher Antti Mutanen from Tampere University of Technology (TUT) has lately done research on customer classification through clustering methods and load profiling based on AMR measurements (Mutanen 2010; Mutanen et al. 2011; Mutanen 2013). Reseacher Matti Mononen from University of Eastern Finland has studied feedback to households on electricity consumption (Mononen et al. 2014). National Consumer Research Centre of Finland has published a report on customers' benefits towards smart grids (Heiskanen et al. 2012).

2 ENERGY EFFICIENCY AND ENERGY CONSERVATION

Energy efficiency and energy conservation are energy reduction techniques. Energy efficiency refers to using less energy for a constant service without reducing comfort. A bit broader theme, energy conservation, refers to reducing energy through using less of an energy service. These themes have got such a central role in politics nowadays because of wills to reduce emissions of greenhouse gases, to secure energy supply and to protect a competitive price of electricity, which all are besides sustainability the corner stones in the EU's energy policy. (European Commission 2012)

Solving environmental questions is the greatest challenge for energy sector and energy reduction is an important method for meeting that. Also energy users are more and more interested in reducing their consumption because of increased prices and a concern about the Earth's state of future for following generations. Thus, enhancing efficient use of energy is a central method for solving challenges from the viewpoints of both society and users. (Finnish Energy Industries 2008, Motiva Oy 2009a)

The reasons behind increased will for energy efficiency, the EU's energy and climate package, the Energy Efficiency Directive, national Energy Efficiency Agreements in Finland and motives of DNOs towards energy efficiency are dealt in this chapter.

2.1 Increased will for energy efficiency

Energy issues are essential for the European Union. The EU wants to address the major energy challenges, its increasing dependence on imports, strain of energy resources and access for all users to affordable and secure energy. The prospect of sharply rising energy prices and increasing dependence on imports makes Europe's energy supply less reliable and risks the whole economy (European Commission 2012).

2.1.1 Reducing emissions of greenhouse gases

Awakening for greenhouse gases intensively increasing greenhouse effect caused increased concern towards climate change through the 20th century. Finally in United Nations Conference on Environment and Development (UNCED) in 1992, which was held in Rio de Janeiro, the United Nations Framework Convention on Climate Change (UNFCCC) was adopted. As a result, the Kyoto Protocol, an international treaty aiming to reduce emissions of greenhouse gases, was adopted in Kyoto, Japan, in 1997. The Protocol sets binding obligations on industrialized countries and it includes two commitment periods. The first commitment period applied to emissions between 2008 and 2012 and the second period applies to emissions between 2013 and 2020. The second commitment period was adopted in Doha Climate Change Conference in December 2012. (United Nations 2013) In future, decisions have to be done to cut our emissions and restrain climate change (European Commission 2012).

Resources of fossil fuels will not last forever. Remarkable portion of future energy demand will still be supplied with fossil fuels. Therefore, energy efficiency is needed for bringing products and services with as little energy use as possible. Without a doubt, also new energy technologies are needed to develop. Nevertheless, energy efficiency has two complementary targets: it decreases energy costs and reduces harmful emissions. (Confederation of Finnish Industries 2013a)

2.1.2 Securing energy supply

Total energy and electricity consumption will grow globally in future. The amount of electronic devices is increasing all the time. Thus, dependence on energy and its distribution channels will increase in future. Here in Finland, energy is a much more important input for industrial life than in EU countries in average due to geographical issues and energy intensive industry (Confederation of Finnish Industries 2013a). In Finland, electricity consumption is estimated to grow although total energy consumption is estimated to decrease and electricity consumption has actually decreased from 2007 levels because of the economic downturn.

The Finnish Energy Industries (ET), an industrial policy and labor market policy association representing the electricity and district heating industry in Finland, and Confederation of Finnish Industries (EK) have published estimations about electricity consumption increasing in future. The estimations are based on assumptions on development of energy sector and views on development of energy efficiency and population growth. They estimated in 2009, in the middle of the latest economic downturn, that the electricity consumption will be 100 – 111 TWh in Finland in 2030 whereas it was 87 TWh in 2008, 90 TWh in 2007, 79 TWh in 2000 and 62 TWh in 1990. (Confederation of Finnish Industries & Finnish Energy Industries 2009)

The consumption in Finland in a period 1980-2012 is seen in Figure 2.1. It is notable that the growth of electricity use is estimated to be slower compared to the past, time before the economic turndown starting in 2008. In seventeen years from 1990 to 2007 the consumption increased 28 TWh whereas it is estimated to increase 13 – 24 TWh in 22 years from 2008 to 2030.

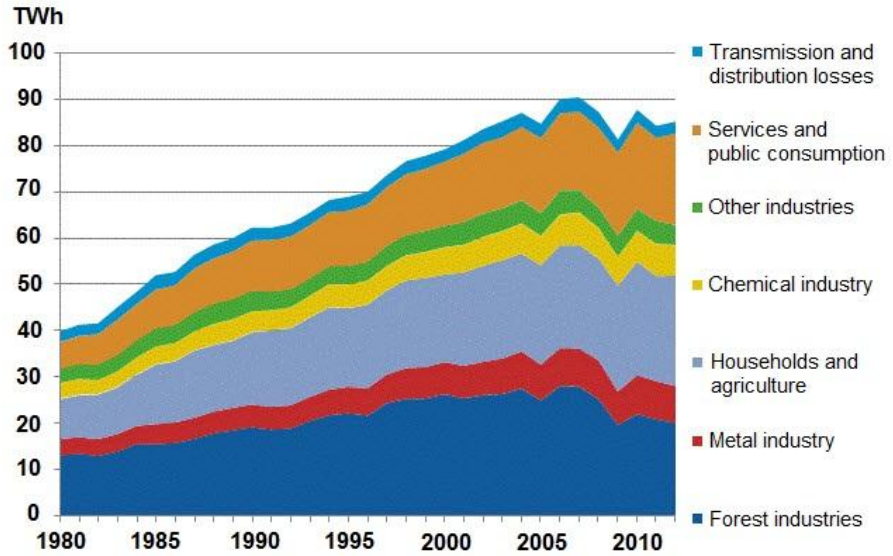

Figure 2.1. *Electricity consumption in Finland in 1980-2012. (Finnish Energy Industries 2013)*

Figure 2.2 presents the structure of total electricity consumption in Finland in 2012. According to the figure, industrial area uses approximately half from the total consumption. Industrial area is already attracted into more efficient electricity use by national Energy Efficiency Agreements, which are dealt in Chapter 2.4. On the other hand, fifty one percent from consumption is used for housing, agriculture, service and building, but mostly they do not belong under Energy Efficiency Agreements.

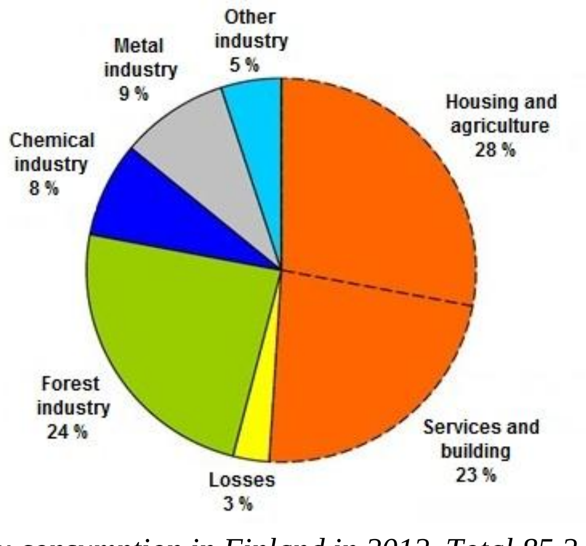

***Figure 2.2**. Electricity consumption in Finland in 2012. Total 85,2 TWh. (OSF 2013a)*

So, there still lay a great electricity reducing potential in the groups marked with an orange color. Besides, Ministry of Employment and the Economy of Finland (TEM) has defined that the biggest energy savings in addition to comprehensive Energy Efficiency

Agreements are available in transportation, buildings and increased energy efficiency of appliances (Confederation of Finnish Industries & Finnish Energy Industries 2009).

In addition to increased electricity consumption and dependence on electricity, peak load consumption is also an important factor as dealing with secure electricity supply in Europe. During peak loads more power generation is needed and power plants ramped up for peak demand are often more polluting and use more expensive fuels. Besides, peak demand may exceed the maximum supply level that the power industry can generate which may result in power outages and load shedding.

Actualized peak load consumption until 2012 and estimation of future trend to 2015-2030 is presented in Figure 2.3. Peak load consumption is estimated to grow notably but for instance the effects of increased energy effectiveness decrease the maximum peak load. Thus, beside DR and other peak load cutting methods, energy efficiency and energy conservation are defined important solutions in cutting peak load consumption. (Confederation of Finnish Industries 2013b)

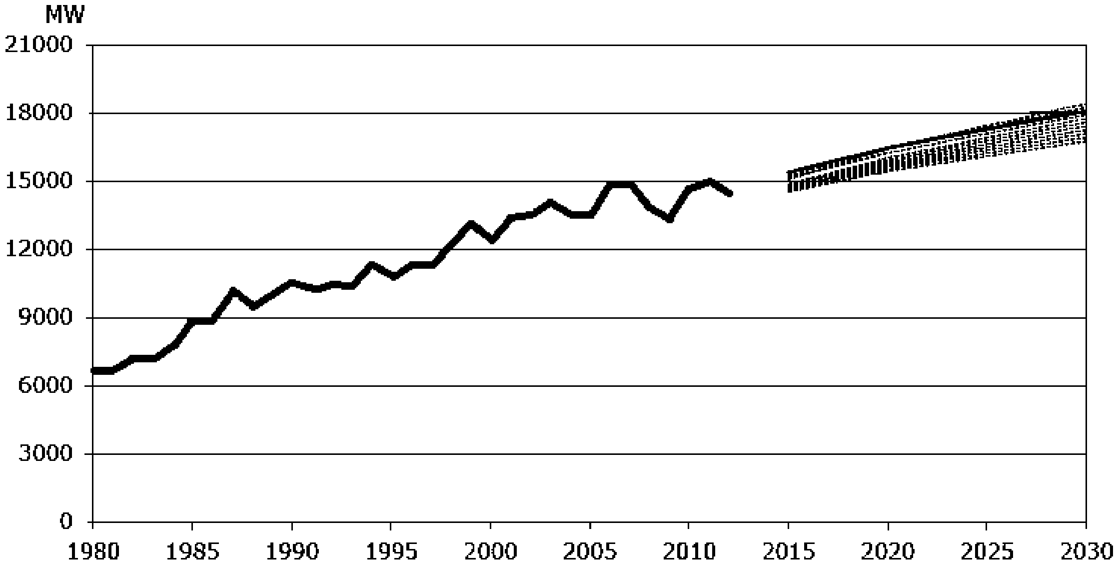

Figure 2.3. *Actualized peak load consumption and estimation to 2015-2030. (Confederation of Finnish Industries 2013b)*

2.1.3 Protecting the competitive price of electricity

The third main goal in European energy policy is to protect a competitive price of electricity and other energy forms as well. The prospect of sharply rising electricity prices risks the whole economy (European Commission 2012).

The price of electricity has increased remarkably among the household consumers in Finland during previous ten years as it is shown in Figure 2.4. According to a research made by Motiva Oy in 2009, monetary costs are the most important factor why consumers would like to reduce their consumption (Motiva Oy 2009a).

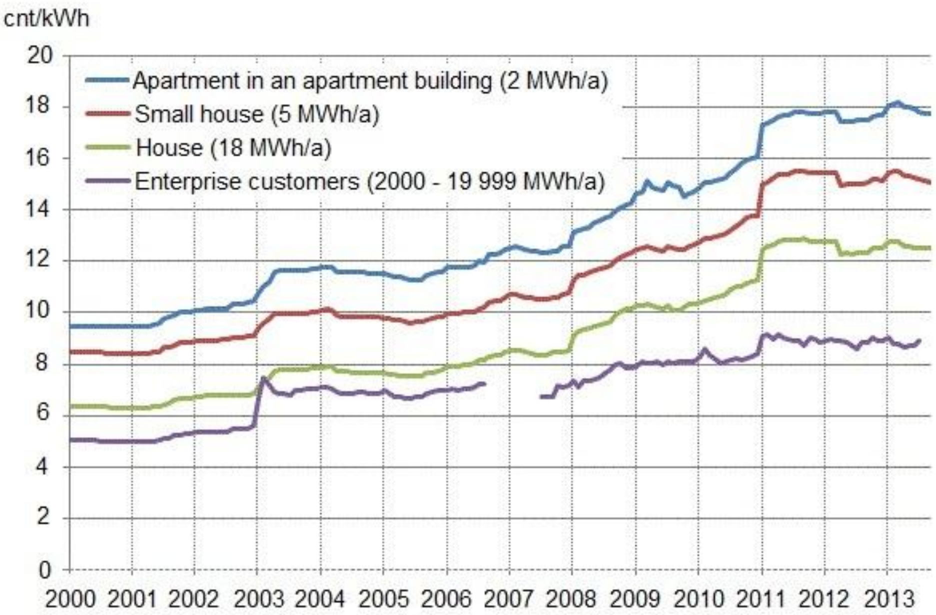

Figure 2.4. *The price of electricity in Finland by different types of consumers. (Energy Market Authority 2013)*

2.2 The EU climate and energy package

The countries in Europe are well aware of the advantages of coordinated action in such a strategic field as energy. That has led to common rules throughout Europe and a pooling of Europe's efforts to secure energy at an affordable price while generating less polluting production. Our standard of living requires huge amounts of energy and that obviously generates pollution, whose impact needs to be reduced as far as possible. That is why Europe has to be effective, set ambitious goals and work together. (European Commission 2012)

The EU has wanted to create commitments for its member countries in their climate and energy politics. European Union formed a distinct and ambitious climate and energy policy in March 2007. The EU Heads of State and Government set an ambitious climate and energy package which is also known as "20-20-20" targets. The targets set three key objectives for 2020 which are a 20 % reduction in EU's greenhouse gas emissions from 1990 levels, raising the share of EU's energy consumption produced from renewable resources to 20 % and a 20 % energy savings especially by improving energy efficiency. The last one refers for a 20 % cut in Europe's annual primary energy consumption by 2020 compared to estimated consumption level with no remarkable changes in energy use in 2020 at the time of setting the target in 2007. However, the climate and energy package does not address directly to the target of energy savings. This is done through the Energy Efficiency Directive. (European Commission 2010)

2.3 The Energy Efficiency Directive

The European Parliament and Council set the Energy Efficiency Directive (2012/27/EC) on energy efficiency and amending the directives (2009/125/EC) and (2010/30/EC) on 25th October 2012. The Energy Efficiency Directive (EED) came into force on 4th December 2012. It also repeals the Energy Services Directive (2006/32/EC) on energy end-use efficiency and energy services and the CHP Directive (2004/8/EC).

Finland's energy saving plans and commitments are based on the EU's directives. The former directive concerning energy efficiency, Energy Service Directive (2006/32/EC), was set in 2006 and repealed by the EED. However, the commitments from the previous directive were also taken along in the newer directive.

The EED is the most important tool for meeting the EU's 20-20-20 target. It will have an effect on companies mainly operating in energy sector. The Directive sets requirements on countries and companies but also enables new business opportunities. According to the EED, the national execution plan meeting the target has to be ready at last on 5th June 2014. The Commission will state comments on the national execution plans on 30th June 2014.

ET has stated that the EED still includes many additional obligations to companies in energy sector. There are still some unclear constructions and too many details included, but these can be clarified until national enforcement deadline on 5th June 2014. (Finnish Energy Industries 2012)

The EED includes several Articles concerning energy use in different operational sectors. The Article 7 is held to be the most important Article for energy sector and DNOs. Finland officiated to European Commission an action plan in December 2013 which aims to implement a cumulative energy saving targets according to the Article. In Finland the cumulative energy savings target is 65,3 TWh which refers to around 2,3 TWh new annual energy savings in 2014-2020. Twenty five per cents from the total energy savings target can be defrayed with actions executed in 2009-2013. That refers to 16,3 TWh. Such earlier actions are for example results due to vast Energy Efficiency Agreements which have been running in Finland since 1997. In period 2009-2013 the agreements resulted a cumulative 53 TWh energy savings which over three-times the amount that can be involved in early actions. Anyway, the agreements have also a key role in an action plan for 2014-2020 officiated to European Commission as it has been estimated they can defray at least half of Finland's total energy savings target during the period. (TEM 2013)

As a point of view to consumers, major energy saving possibilities for consumers are defined in EED as easy and free-of-charge access to data on real-time and historical energy consumption. More accurate smart meters will now empower consumers to better manage their energy consumption.

2.4 National Energy Efficiency Agreements in Finland

Energy sector in Finland has already engaged for enhancing energy consumption of energy producers and final customers and sector's own use. The current voluntary Energy Efficiency Agreements 2008-2016 are following the voluntary energy savings agreements started in 1997 launched by Ministry of Trade and Industry. After that the agreements have become really popular in Finnish industries as over half of Finland's final energy use belongs under the agreements. (Finnish Energy Industries 2008) Now the Energy Efficiency Agreements have a big role in meeting the targets in EED.

The Energy Efficiency Agreement is a general agreement between Finnish Government and Finnish industries. The aim of the agreement is to enhance Finnish companies' energy use from their own will. The current agreement is valid for period of 2008-2016 as the Energy Services Directive (2006/32/EC, repealed by the EED) has set a target for cutting the consumption by 9 % until the year 2016 (Finnish Energy Industries 2008). Comparison is done to an average energy use between years 2001 and 2005. The target of nine per cents refers to 17,8 TWh of energy (Finnish Energy Industries 2008).

The parties involved in the agreement are TEM, EK and business associations which are main links for most companies for signing the agreement. Companies can also join the agreement directly by signing via EK, and a company has to do it directly if one of its business sites consumes energy more than 100 GWh per year. TEM and EK would like as much energy use of Finnish industries as possible to join the agreement. As incentives for joining the agreement, the Government offers raised energy supports for energy audits and energy saving investments. (Confederation of Finnish Industries 2014)

Different sectors such as energy usage, distribution and production are involved in the agreement. Different business sectors have different operation programmes, which give more exact numbers and meters for defining company's results on its energy efficiency activities. (Confederation of Finnish Industries 2014)

Required actions for energy companies are mainly directed towards households. One of the main targets is to get energy services aiming for enhancing consumers' final energy use to be included in companies' normal operation. Primary stress is in development of consumers' consumption monitoring, for instance by systems offering consumption feedback so that consumers have data enough on their consumption levels for being able to execute energy effective actions (Finnish Energy Industries 2008). Other suggestions are communications about energy efficiency, interactive energy saving advices, comparisons to both historical consumption and similar consumers and development of new energy services and energy effective actions. (Motiva Oy 2012)

Energy Efficiency Agreements also set targets for company's own use. However, as their energy use may increase due to growth of business, the target has not been defined very accurately. (Confederation of Finnish Industries 2014)

Current agreements end in 2016. For to be sure about the continuity, TEM has already plans about new agreement period starting in 2017. On 29th November 2013

TEM, EK and its business associations signed a statement of intent for achieving together a cumulative energy savings of 28 TWh in the following period 2017-2020. (TEM 2013)

2.5 Motives of DNOs towards energy efficiency

Income of DNOs is directly proportional to the amount of electricity consumed. It is an interesting question why DNOs should put effort on development of enhancing energy efficiency and savings in their operation. They have to do actions to fulfill the commitments but they could also get new interests from energy efficiency.

2.5.1 Implementation of commitments

Many DNOs have signed the Energy Efficiency Agreement which was presented in Chapter 2.4. As the agreements are nowadays related to implementation of Energy Efficiency Directive, the most significant parts of the EED are introduced next from the viewpoint of DNOs. Until the end of 2011 totally 49 Finnish DNOs have joined the agreement (Motiva Oy 2012).

Article 7: Energy efficiency obligation schemes
The primary commitment in this scheme is that a member state sets up an energy efficiency obligation scheme which ensures that DNOs and energy sales companies achieve a cumulative end-use energy savings target by 31st December 2020. The savings target is equivalent to achieved new savings each year 2014-2020 of 1,5 % from the annual energy sales to final consumers by volume of distribution or sales. An averaged value of volume over the years 2010-2012 is used as a base number in a calculation of the target. The Commission will state comments from each member state on implementation plans of the Article 7 on 30th June 2016.

Article 9: Metering
Final consumers for electricity, natural gas, district heating and cooling and domestic hot water are provided with competitively priced individual meters that reflect actual energy consumption and that provide information on actual time of use. Security of smart meters and data communication and privacy of final customers should be ensured. Meters should be ensured that they can account for electricity put into the grid from consumer’s premises. Advice and information shall be given to consumers at the time of installation.

Article 10 Billing information
Final consumers shall have a possibility for easily accessing to complementary information on historical consumption allowing detailed self-checks. Historical consumption shall include

- *Cumulative data for at least the three previous years or the periods since the start of the supply contract if this is shorter*
- *Detailed data according to the time of use for any day, week, month and year. These data shall be made available to the final customer via the internet or the meter interface from at least the previous 24 months or the period since the start of the supply contract if this is shorter.*

If a customer does not have a smart meter, billing information shall be accurate and based on actual consumption by 31th December 2014. If a customer has not provided a meter reading, billing shall be based on estimated consumption. Whether a customer has a smart meter or not, electronic billing information shall be made possible.

Article 11 Cost of access to metering and billing information
Free-of-charge billing information should be offered to a final customer and ensure they also have access to their consumption data in an appropriate way and free-of-charge.

Article 12 Consumer information and empowering programme
Member states should take measures to promote and facilitate an efficient use of energy for private customers. For example fiscal incentives, information, exemplary projects and workplace activities are mentioned as policies to promote behavioral change. Cost-effective and easy-to-achieve changes in energy use and information on energy efficiency measures are mentioned as ways of communication to engage consumers.

Article 15 Energy transformation, transmission and distribution
National energy regulators should pay due to energy efficiency in their actions and operation. The most important content in this article for DNOs is the Annex XI about detailed regulations on network tariffs. However, they are not very relevant in this Thesis so they are not dealt here.

2.5.2 Improved customer service and possibilities on new services

There is a chance for DNOs to improve their reputation as a customer-oriented partner. With improved services and functionalities customer service will improve and that may increase the satisfaction towards a service supplier. Also consecutive costs of customer service will decrease as more people could take care of their needs online and thus customer servants will have time for other business. Besides, energy services offered by an energy company is desirable as, according to a survey made by Motiva Oy in 2009, the most pleasant partner for giving energy saving tips is an energy company (Motiva Oy 2009a).

With consumption reporting services, there is a possibility that consumers start shifting loads on different periods which may result on peak loads being cut. New services can be used for improving customers' knowledge about their effectiveness in use of electricity. DNOs could for example start thinking in cooperation with suppliers and system providers on utilizing home energy management systems (HEMS), which may be used on load-shifting and DR as well.

2.5.3 Advantages compared to electricity supplier's reporting

The law requires an electricity sales company to provide final users at least once a year a report on their consumption. The report had to be provided to the users firstly at last in 2011. The report has to show consumer the consumption from the period of the report and from previous three years, or up to the time the customer relationship has lasted if the relationship has lasted shorter. The report has to include comparison data from similar final users. The comparison data had to be shown on the report at last in 2012. Besides, the report must contain data about actions improving energy efficiency and contact information of such parties who can give more information about the actions. There is no more accurate definition in law about the form of feedback data. (Adato Energia Oy 2010)

As the report has to be provided to final users at least once a year, the most probable form of the report is paper report along a bill as there is no certainty that all the customers would use an online reporting service. However, online energy reporting services can be more useful and include more information about the consumption, comparisons and others. In online service a consumer could for example define to which kind of consumers he or she wants to compare the own consumption. With this they could for instance examine the probable effects due to change of consumption habits. Online reporting service can be far more versatile than a paper report. Online service is also available at the time a consumer wants to view the consumption data.

3 ELECTRICITY CONSUMPTION OF PRIVATE CONSUMERS

Often, electricity consumers do not know if their consumption is relatively high or low. Thus, a consumption feedback is important to get them to understand their consumption levels and further change their behavior into more effective use of electricity. In many researches consumers have answered a proper feedback would be a data on own consumption and a possibility to compare it to one’s past consumption and consumption from similar consumers. (Motiva Oy 2009a; Vattenfall Verkko Oy 2011) Comparison to consumer’s past consumption is easy to carry out but comparison to similar consumers instead is much more challenging.

Load profile models only classify consumers according to their load profile. They do not consider similarities between customers. For being able to compare similar electricity consumers properly the consumers need to be classified to different groups with similar factors. Consumers have different reasons and factors to consume electricity. In other words, there are several kinds of electricity users and even the users with similar consumption explaining factors may have great differences in their consumption. A psychological aspect on consumption behavior is very challenging to examine so it is not included in this thesis.

Consumption explaining factors of private customers of Elenia Oy, the ones with a main fuse size of 3x63A or less, are dealt in this Chapter. This kind of dealing is done because the online energy reporting service of Elenia is divided into private customers and enterprise customers according to this bound. However, even this group of private customers contains significantly different customers for example households, farms, leisure time apartments and several types of business apartments. Main focus in this thesis is held in household customers as they are overwhelmingly the largest group.

3.1 Consumption-explaining factors in households

Factors affecting to electricity demand in households are a type and size of an apartment, a main heating mode of an apartment, ancillary heating systems, geographical location, a number of residents, a type of residents, a building year, building attributes of an apartment, types and amount of electrical appliances and an income level of residents. (Fell & King 2012; Adato Energia Oy 2013) It can be guessed that people with larger incomes have the ability to buy more appliances, but on the other hand, they may also buy more energy effective appliances. However, as gathering income data from customers is difficult and questionable in practical, the analysis of effects of income level is left out from this thesis.

Results from a research on electricity use of households in Finland in 2011, published by Adato Energia Oy, are used a lot in this Chapter to clarify the consumption explaining factors. Adato Energia Oy is a Finnish energy company founded in 1989 and it is primarily a service company for Finnish energy companies. Adato Energia Oy has also earlier done researches on electricity use in Finland, published in 2006 and 1993, so comparison in consumption change among households can also be done. Unfortunately no reliable data on households' consumption before 1993 is available, so long-time comparison cannot be done.

As a basis for the latest research was an inquiry for which the consumption data was collected from a DNO with a permit from each customer. The inquiry was gathered for estimating consumption of different appliance groups and updating example households used in DNOs customer communication. Consumption factors are divided in two larger groups: home appliances and heating. The inquiry was modeled based on earlier consumption data and a data about consumption of different electrical appliances gathered from different references. The results of the research were consumption levels of appliance groups and consumption data of example households. The results concern electricity consumption in permanently lived households. The research neither deals with electricity use of real estate properties, business apartments et cetera. (Adato Energia Oy 2013).

As an introduction to following, consumption of households in a period 2006-2011 has increased almost 2 TWh and the increase is almost totally related to electricity use for heating, which will be seen in Tables 3.2 and 3.7. The total electricity consumption was 19237 GWh in 2011, 17670 GWh in 2006 and 14362 GWh in 1993. Also the number of households has grown during the period but still electricity use for heating has increased relatively quicker than the amount of apartments. (Adato Energia Oy 2013) Since 1990 a housing stock has increased with 30 000 apartments per year in average (OSF 2013b).

3.1.1 Type and size of an apartment

Type and size of an apartment have a big effect on its consumption level. In addition, there is usually a prominent relation between them: detached houses are bigger than row houses and row houses are bigger than apartments in an apartment building which can be seen in Table 3.1. Size of apartments has grown through the years, especially in detached and semi-detached houses. In 2012 the average surface area of a house was 79,7 m^2. The average size has grown around 20 m^2 from the 1970. Average sizes of households in regions of Elenia's network in 2012 are seen in Table 3.6. Households in Southern and Northern Ostrobothnia are relatively bigger than in other regions in Elenia's network domain.

Table 3.1. *Average surface area (m^2) per house or apartment by type of house in 1970-2012. (OSF 2013b)*

Year	Type of house or apartment				
	All [m^2]	**Detached or semi-detached [m^2]**	**Row house [m^2]**	**Apartment building [m^2]**	**Others [m^2]**
1970	60,0	66,0	73,0	51,0	54,0
1980	69,3	83,6	71,7	54,8	55,5
1990	74,4	95,3	70,2	55,8	59,7
2000	76,5	101,9	70,0	56,1	59,8
2010	79,5	108,4	71,2	56,5	60,7
2012	79,9	109,5	71,3	56,5	61,1

As comparing values in Table 3.1 to the values of electricity use for heating and appliances in households in Tables 3.2 and 3.7, it is seen that all of them have grown. When sizes of apartments are growing, more energy is needed for heating as more air has to be warmed up to the required temperature. Besides, bigger apartments usually contain more electrical appliances. For example, in 1993 electricity consumption of appliances was 7468 GWh whereas in 2011 it was 9744 GWh. Electricity consumption of heating was 6894 GWh in 1993 and 9493 GWh in 2011. (Adato Energia Oy 2013)

Because bigger apartments need more electricity for heating and there are probably more electric appliances, comparison between totally different sized apartments may not be relevant. However, different sized apartments may have a similar load profile. Besides, consumption levels of different sized apartments can be similar due to different consumption behavior and habits.

Not all the electricity consumption is usually billed from a customer by a DNO or energy supplier in an apartment building or row house; they pay some of the use in their maintenance charge. For example, electricity for heating and warm water is usually measured commonly by a real estate property for all its apartments. In other words, a DNO is not conscious on how much electricity is totally needed in a single apartment or row house. As an exception, there are row houses especially which pay for their heating straight for a DNO and an energy supplier. Consumers living in a detached or semi-detached house mainly pay for all the electricity consumption for a DNO and an energy supplier. (Adato Energia Oy 2013) Dealings of different sized apartments and different types of apartments for comparison are dealt more in Chapter 5.

3.1.2 Main heating mode

Main heating mode is one of the most determinative factors for electricity use in apartments in Finland because certain inside temperature is needed for living in a cold country. Different heating modes consume various amounts of electricity.

Main heating modes in households in Finland are usually traditional electric heating, accumulating electric heating, district heating (DH), geothermal heating, various air heat pumps and boilers using oil, wood, pellets or gas (Motiva Oy 2013). Households may also have sort of combinations of heating modes or ancillary heating systems which are dealt in following chapter 3.1.3. Figure 3.1 presents the market share of heating systems in new small residential buildings in Finland in 2006-2011.

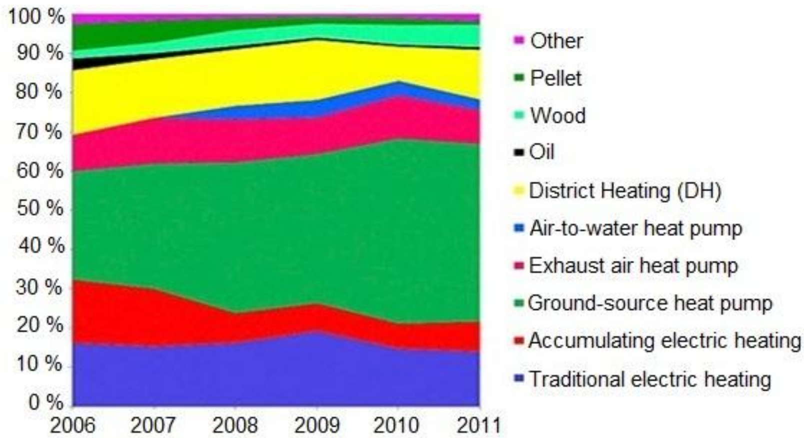

Figure 3.1. *The market share of heating systems in new small residential buildings in Finland in 2006-2011. (Motiva Oy 2013)*

In traditional electric heating the area is straightly heated with electricity via radiators or cables under floor or inside a roof. In accumulating electric heating heat is stored into an accumulator and released when required. Usually the heat is stored in water inside the accumulator and then released via ducts into rooms. The difference to the previous mode is that accumulating electric heating systems usually take advantage of cheaper electricity prices so basically they are switched on overnight and release the heat during the day. Traditional and accumulating electric heating are the most electricity-consuming heating modes, although in accumulating heating the losses of energy are bigger. (Motiva Oy 2009b; Motiva Oy 2013)

Geothermal heating takes advantage of heat stored in the ground. In Finland, the ground heat can be enhanced with ground-source heat pumps. The compressor of the pump needs electricity for operating. The pumps can be measured for partial or full power. Partial power means that the electric resistors of the pump are defined to operate after the relative set value from calculatory peak load demand is exceeded. When operating with full power, the resistors are not measured to switch on. (Motiva Oy 2013)

Also air heat pumps use electricity to function. Usually air heat pumps used as a main heating mode of a household are air-to-water heat pumps and exhaust air heat pumps. Air-to-air heat pumps are mainly used for ancillary heating. (Motiva Oy 2013)

Little electricity-used systems are district heating and different boilers using oil, wood, pellets or gas Boilers may have auxiliary resistors combined to them so that the release of heat will not stop if the main fuel runs out (Motiva Oy 2009b) Electricity consumption in apartments using DH is distinctly lower than with other heating modes (Adato Energia Oy 2013).

Electricity for heating in Finland in 2006 and 2011 is presented in Table 3.2. The bolded main groups are *apartments with no electric heating, heat pumps with circulated water system and traditional electric heating*. Also consumption of *water heating, additional or outdoor buildings* and *cooling* are presented. (Adato Energia Oy 2013)

Table 3.2. *Electricity for heating in Finland in 2006 and 2011. The values and percentages are represented from the total electricity consumption in Finnish households. (Adato Energia Oy 2013)*

	2006		**2011**	
	GWh	**%**	**GWh**	**%**
Water heating				
Room-based	1242	7	1307	7
Central heated	250	1	520	3
Apartments with no electric heating, ancillary heating				
Floor heating	206	1	464	2
Heat pumps	50	0	142	1
Others	60	0	122	1
Heat pumps with circulated water system				
Geothermal energy	125	1	287	1
Other circulated water heat pumps	60	0	79	0
Ancillary heating with electricity	20	0	29	0
Traditional electric heating				
Room-based	4823	27	4562	24
Water tank, resistor	550	3	681	4
Ancillary heating with electricity	400	2	485	3
Electric heating: additional or outdoor buildings				
Additional and outdoor buildings	209	1	303	2
Cooling				
Cooling	0	0	46	0
Total	**7996**	**45 %**	**9493**	**50 %**

In the group of *apartments with no electric heating* electricity is used for ancillary heating. Such apartments are: all central heated row houses and apartments in apartment buildings, and central heated detached or semi-detached houses with DH, oil, wood and pellets as their main heating mode. In addition, all apartments with room-based heating with wood or pellets are also included in this group. (Adato Energia Oy 2013)

Group of *heat pumps with circulated water system* include ground-source heat pumps, air-to-water heat pumps and part of exhaust air heat pumps. Majority of them are ground-source heat pumps, which generalize quickly at the moment. Group of *traditional electric heating* include apartments with room-based electric heaters and circulated water systems which have a resistor in a water tank. In these groups the rows *Ancil-*

lary heating with electricity in Table 3.2 consists of consumption on floor heating, air heat pumps and separate electric heaters. (Adato Energia Oy 2013)

It is seen in Table 3.2 that traditional electric heating takes around half of electricity for heating households. There is a slight decrease in traditional electric heating as consumption has dropped from 27 % to 24 %. As a background of a decrease are three factors: At first the ancillary heating systems, as around 40 % of the apartments with room-based traditional electric heating have an air heat pump. Secondly, in around 75 % of apartments with room-based traditional electric heating wood is also used for heating. Thirdly, other heating modes have become more common. (Adato Energia Oy 2013)

Geothermal heating has more than doubled in 2006-2011. That is also seen in a little increase in water heating. Heat pumps are also becoming more common as a main heating mode in both new buildings and when renovating old buildings. That increases electricity consumption in a large scale because heat pumps often replace heating systems that do not use electricity for operation. (Adato Energia Oy 2013)

3.1.3 Ancillary heating

Ancillary heating systems are used for getting the costs of bought energy lower. Fireplaces, floor heating and air heat pumps are mainly used ancillary heating systems. Accumulating fireplaces can also be used for heating water in a central water unit. As observing electricity consumption of households, ancillary heating is smart to classify for ones using electricity and not using electricity. Non-electrical ancillary heating usually decreases electricity consumption in an apartment and that may be the target also in electrical ancillary heating but it may also increase electricity consumption even as total energy costs would decrease.

Electricity use for ancillary heating in Finland was also presented in Table 3.2. Ancillary heating systems have become more popular beside a main heating mode in each main group in the Table, especially in the group *Apartments with no electric heating*, where electricity consumption of ancillary heating has more than doubled in 2006-2011. In that group consumption is divided into three groups: floor heating, heat pumps and others. The biggest one is floor heating. Heat pumps are mainly air heat pumps. Others include separate electric heaters and equivalents. (Adato Energia Oy 2013)

Table 3.3 presents popularity of each ancillary heating mode in detached houses with water tank system in 2011.

Table 3.3. *Ancillary heating modes in detached houses with water tank system in 2011. DH means district heating and GH is geothermal heating. (Adato Energia Oy 2013)*

Main heating mode	DH	Electricity, water tank	Oil	GH	Wood, pellet
Ancillary heating connected to circulated water system					
Air-water HP	3 %	10 %	11 %	2 %	6 %
Exhaust air HP	1 %	15 %	1 %	2 %	1 %
Fireplace, circulated water	5 %	6 %	2 %	5 %	5 %
Auxiliary resistor in boiler		3 %	32 %	19 %	73 %
Boiler with two fireplaces		5 %	16 %		13 %
Solar collector	0 %	2 %	2 %	1 %	6 %
Separate ancillary heating					
Fireplace	52 %	76 %	44 %	75 %	58 %
Air-to-air heat pump	7 %	28 %	22 %	10 %	13 %
Floor heating in bathroom	30 %	34 %	28 %	10 %	17 %
Floor heating elsewhere	9 %	30 %	13 %	6 %	11 %
Separate electric heaters	15 %	17 %	15 %	12 %	18 %

Many apartments with a main heating resource from wood or oil have ancillary heating systems nowadays. In 2006 research a big part of consumption could not be clarified especially in non-electrically heated detached houses with a main heating resource from wood or oil. That was supposed to result from ancillary heating. In 2011 research that suppose became true. With air-to-air and air-to-water heat pumps ancillary electric heating has increased especially in oil-heated small houses. Also floor heating comes more common as a heat distribution mode in new buildings. Electric pumps of floor heating consume around 25 % more electricity than the ones in electric heaters. (Adato Energia Oy 2013)

3.1.4 Geographical location

Geographical location correlates rather relatively to apartment's consumption levels. This is because of differences on environmental issues such as temperature, strength of wind and amount of sunlight (Siirto 1989; Seppälä 1996). As the network domain of Elenia Oy is rather large the temperatures vary a lot between different regions in Elenia's network that are presented in Figure 3.2.

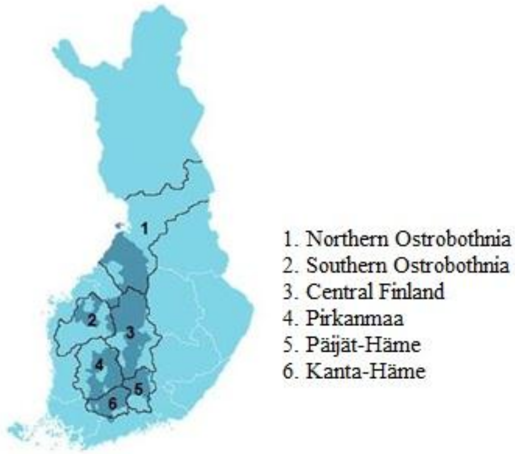

Figure 3.2. *Regions of network domain of Elenia Oy. Regions are marked with numbers and the network domain is marked as navy-blue color. (Modified from Elenia Oy 2014).*

Table 3.4 shows monthly average temperatures in the regions of Elenia's network. The temperatures are long-time average values measured between 1981 and 2010. The values are sufficient for examining areas of Elenia's network as Northern Ostrobothnia is the only region from which large parts extend out of it. However, the values in the Table from Northern Ostrobothnia are measured from the western part of the region, so they are also valid as the network is also there.

Table 3.4. *Monthly average temperatures in the regions of Elenia Oy's network area in 1981-2010. (Pirinen et al. 2012)*

	Kanta-Häme [°C]	Päijät-Häme [°C]	Pirkanmaa [°C]	Central Finland [°C]	Southern Ostrobothnia [°C]	Northern Ostrobothnia [°C]
January	-5,6	-6,4	-6,4	-8,3	-7,5	-9,6
February	-6,3	-7	-6,9	-8,5	-7,8	-9,3
March	-2,4	-2,7	-2,8	-3,8	-3,4	-4,8
April	3,5	3,5	3,3	2,2	2,7	1,4
May	9,8	10,1	9,7	8,9	8,9	7,8
June	14	14,4	14,1	13,7	13,6	13,5
July	16,7	17,2	16,9	16,5	16,2	16,5
August	15	15,1	15	14,1	14	14,1
September	9,9	9,7	9,8	8,8	9	8,9
October	4,9	4,6	4,6	3,6	4	3,3
November	-0,2	-0,6	-0,6	-2	-1,5	-2,8
December	-3,9	-4,5	-4,5	-6,2	-5,6	-7,1
Year	**4,6**	**4,5**	**4,4**	**3,3**	**3,6**	**2,7**

According to Table 3.4, the average temperature values from Kanta-Häme, Päijät-Häme and Pirkanmaa are very close to each other every month. Values from Southern Ostrobothnia and Central Finland are also rather close to each other. Northern Ostrobothnia differs from the others being the coldest region of them. Thus, three groups, south, middle and north could be found for similar outdoor temperatures.

3.1.5 Number and type of residents

A number of residents usually has an effect on apartment's consumption. The amount of appliances and equipment mainly increases and they are used more as more people live in an apartment (Adato Energia Oy 2013). Table 3.5 presents relative amount of Finnish households according to the type of apartment and number of residents.

Table 3.5. *Relative amount of Finnish households according to the type of apartment and number of residents. (Adato Energia Oy 2013)*

Residents	**Detached or Semi-detached house**	**Row house**	**Apartment building**	**Others**	**Total**
1	8 %	6 %	25 %	1 %	**40 %**
2	15 %	5 %	13 %	1 %	**33 %**
3	7 %	2 %	3 %	0 %	**12 %**
4	7 %	1 %	2 %	0 %	**10 %**
5+	4 %	0 %	1 %	0 %	**6 %**
Total	**41 %**	**14 %**	**43 %**	**2 %**	**100 %**

The amount of apartments with one or two residents have increased many decades in Finland, being 73 % of all year-round-lived apartments in the end of 2012. It is also seen that most households in Finland are ones in apartment buildings (43 %) or detached or semi-detached houses (41 %).

However, although 41 % of the apartments are detached or semi-detached houses about half of the Finns live in those. Besides, only third of the population live in apartment buildings though 43 % of the apartments are that type. This is explained as apartments in apartment buildings are smaller and there live smaller families or residential groups than in row houses and detached or semi-detached houses. (OSF 2013b)

There was regional variation in number of residents in households. In city-like municipalities the average size was 2,00 people whereas in rural-like municipalities the value was 2,17 people. There are more single-living apartments in urban-like municipalities than in rural-like ones. (OSF 2013b) Number of residents and surface area per a household locating in Elenia's network are presented in Table 3.6.

Table 3.6. *Number of residents and surface area per a household in the regions of Elenia's network on 31st December 2012. (Modified from OSF 2013b)*

Region	Residents/ household	Surface/ household
Kanta-Häme	2,06	84,5
Pirkanmaa	2,03	80,1
Päijät-Häme	1,97	80,0
Central Finland	2,06	81,0
Southern Ostrobothnia	2,20	93,2
Northern Ostrobothnia	2,23	86,7

It is seen from the Table that there are more residents per a household in Southern and Northern Ostrobothnia than elsewhere. As a difference to Table 3.4, where temperatures of Northern Ostrobothnia were measured from the western part of it, now also households in Eastern part of the region are counted into the value in Table 3.6.

Besides number of residents, also the type of residents has an effect on consumption levels and the time of use. Types of residents are for example a family with children, retired couple and single person. For instance, retired or unemployed people tend to spend more time home at workdays.

3.1.6 Construction year

A construction year of a house has been estimated to result strongly for its heating consumption. However, that prediction was not observed in the Adato's research as detached and semi-detached houses with traditional electric heating were examined. The electricity for heating did not decreased as much as it was expected when newer houses were compared to older ones, which is seen in Figure 3.3.

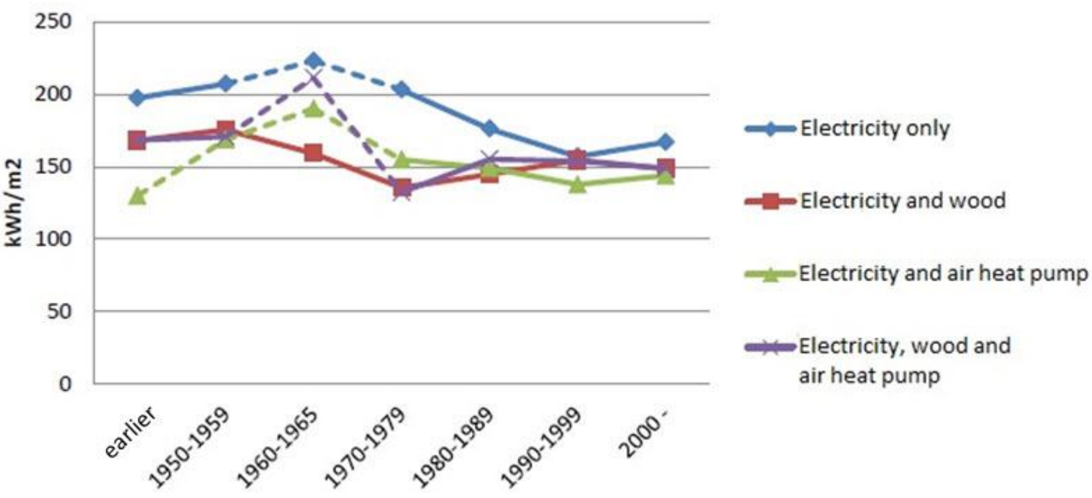

Figure 3.3. *Electricity use per surface area in detached and semi-detached houses with room-based heating according to different combinations of energy sources and construction year. (Adato Energia Oy 2013)*

In houses built after 1980 the electricity needed for heating was very similar. Houses built before 1980 have differences in the need of heating electricity, especially in 1960s built houses as seen in Figure 3.3. It is likely that a lot of repairs have been done in houses built before 1960 and thus their energy efficiency has improved. It is also seen in the figure that ancillary heating decreases the electricity need for heating. The results are found out reasonable as the observed consumption levels in different-aged buildings were well relative to the corresponding values in Norway. Norway is a good comparison country for us because of similar geographical location of population. (Adato Energia Oy 2013)

The construction year of building does not always tell all the truth about its quality of heat storage. Besides, variation in electricity need for heating is large when old houses, built before 1980, are compared to each other. Some of them might have been done a lot of energy efficient improvements whereas some of them have not. Old buildings may actually need less electricity for heating than the ones built much later. Variation is not that large in newer buildings. (Adato Energia Oy 2013)

However, there are notable effects for electricity demand in new buildings as construction requirements have become tighter in last ten years. Especially in new low-consuming houses, for example low energy and passive houses, electricity demand is much lower than in others. This will be dealt more in Chapter 3.3.

3.1.7 Types and amount of electric appliances

The amount of electrical appliances is increasing all the time but the average consumption of new appliances is decreasing. As a background of appliance development are the regulations given by the EU's eco-design requirements which are dealt in Chapter 3.3. For instance, the requirements have turned the direction of electricity use in televisions and lighting to decrease. (Adato Energia Oy 2013)

The popularities of certain appliances in households are shown in Figure 3.4.

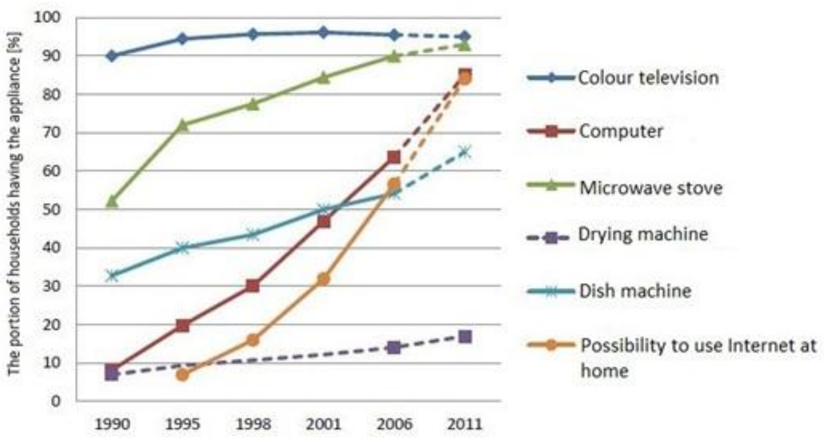

Figure 3.4. *The popularities of certain appliances in Finnish households. (Adato Energia Oy 2013)*

Consumption of household appliances in Finland in 1993, 2006 and 2011 are presented in Table 3.7. Appliances are divided in three main groups: cooking, home electronics and lighting. Consumption of electric saunas and heating, ventilation and air-conditioning (HVAC) are also added to the appliance group, although in Adato's research they had been counted for heating consumption. Reasons of consumption changes in 2006-2011 and future trends on consumption are presented after the table. (Adato Energia Oy 2013)

Table 3.7. *The consumption of household appliances in Finland in 1993, 2006 and 2011. The values and percentages represent the consumption from the total electricity consumption of Finnish households. (Adato Energia Oy 2013)*

	1993		**2006**		**2011**	
	GWh	**%**	**GWh**	**%**	**GWh**	**%**
Cooking						
Stove and others	796	6	653	4	632	3
Home electronics						
Dishwashing	125	1	261	1	367	2
Laundering and drying	316	2	391	2	373	2
Refrigeration equipment	2215	15	1461	8	1410	7
TV and accessories	537	4	834	5	564	3
Computer and accessories	(-)		407	2	848	4
Car heating	226	2	215	1	571	3
Others	623	4	1468	8	1649	9
Lighting						
Indoor lighting	1541	11	2427	14	1230	6
Outdoor lighting	(-)		85	0	290	2
Sum	**6379**	**44 %**	**8201**	**46 %**	**7935**	**41 %**
Electric sauna	606	4	852	5	948	5
HVAC	483	3	621	4	861	4
Total	**7468**	**51 %**	**9674**	**55 %**	**9744**	**50 %**

Cooking
Electricity use in cooking has stayed similar but portion of total consumption has dropped from 4 % to 3 %. That is explained by generalization of micro wave stoves and decrease in amount of cooking with stoves. Generalization of energy effective induction stoves will decrease consumption for cooking step by step as they get cheaper.

Dishwashing
Electricity use has increased from 1 % to 2 % as dishwashers have become more common, which was seen in Figure 3.4. The trend of growth is estimated to continue. On the other hand, generalization of dishwashers reduces use of warm water.

Laundering and drying

There has been no large change in consumption. Drying machines have generalized slowly which was seen in Figure 3.4. Washing machines have been modernized and corresponding improve in energy efficiency due to eco-design directive is seen in a slight decrease of consumption.

Refrigeration equipment

There was a little decrease which results from more effective appliances but also from the decrease of the amount of appliances. Auxiliary devices have become even rare.

Televisions, computers and accessories

Consumption of televisions and accessories has decreased from 5 % to 3 %. That is because, as seen in Figure 3.2, popularity of televisions has not grown anymore and the majority of appliance basis was modernized from traditional cathode ray tube televisions to less consuming table televisions in 2007-2010. Over 1 760 000 table televisions were sold during that period [KOTEK et al. 2008, 2009, 2010]. Besides, also standby consumption in televisions has decreased notably because of eco-design requirements, being under 1 W in most new televisions. The effect from decreased standby consumption is greater than for example the growth of average screen size. In future as the screen size will probably get bigger and standby-consumption cannot be decreased much, the consumption of televisions may turn to growth.

Consumption of computers and appliances has increased because computers and broadband connections have strongly become more common as seen in Figure 3.4 and the time they are used has increased. Even the increased popularity of separate displays and the transition from more consuming desktop computers to laptops have not repealed the increase.

Car heating

Electricity use in car heating has grown because the amount of cars and internal car heaters has increased. However, the values are not comparable as such because the use of car heating varies yearly, and the values in Table 3.7 are not temperature corrected. 2006 was colder year than 2011.

Others

In 2006 research the consumption of group *Others* proved rather large and it is still that although part of it have been transferred to better fitting groups. The group consists of small devices like hair dryers and hoovers, and more rare but lot-consuming devices like waterbeds and big aquariums.

Lighting

Generalization of energy saving lamps has affected a lot in the decrease of consumption. Energy saving lamps consume even 60 per cents less energy than bulb lamps and they may last even ten times longer. In 2006 the portion of total consumption was 14 % whereas it was only 8 % in 2011. The electricity use of lighting has broadly halved in a period 2006 – 2011 although the number of apartments has increased.

Electric saunas

Use of electric saunas has grown in every research. As the number of apartments has increased more electric saunas have also been built.

Heating, ventilation and air conditioning (HVAC)
Mechanical ventilation has generalized in small houses since 1980s and that has increased electricity use in HVAC group.

3.1.8 Distributed generation

Consumer's own power generation reduces the demand of electricity needed from the grid. Usually own power generation, or distributed generation (DG), consists of solar panels, small wind turbines or internal combustion engine generators. DG is still rather rare in Finland but it is expected to become more popular in future. Besides, there will be more electric storages available as well in future as electric vehicles start to become more common. Although electric storages are not considered as generation units, they can be handled as them in this case as they can be used for decreasing the amount of electricity needed from the grid in a certain consumption site.

Consumers who have DG in their site would probably like to see the amount of electricity generated and the amount supplied into the grid. Usually a DNO does not know how much power customer's device has generated as the power does not flow through the AMR-device. The AMR-device only measures the power that flows through it from the grid or into the grid. There are also different smart meters under operation and not all the devices can measure the power into the grid by hourly accuracy.

Thus, the consumers having DG could be showed the amount of electricity supplied into the grid. However, as the measurements of consumption and supply are stored in different consumption sites in MDMS there may be challenges in noticing if a customer logging into the consumption reporting service will have generation on the site. As the supply is measured in the same device than the consumption, the customer relationship management (CRM) software could notice if there are same AMR-devices in different consumption sites behind the connection point. That information could be linked to the consumption reporting service and show the data on supply as well. The values for both supply and consumption have to be presented.

Consumers not having distributed generation however might be interested on levels that DG produces in the area. Thus, customers could be shown average levels of decrease of consumption due to DG. That could be offered by the typical annual levels of different DG systems regionally.

For solar power the time of annual peak generation is around 900 h in Southern Finland and 800 h in Central Finland and Northern Ostrobothnia (Paavola 2013). That means the time in which the yearly energy generated would be generated with a nominal power of a power plant. The nominal power of typical solar systems for private use is usually between 1 kW and 5 kW. Thus, the yearly energy generated in Central Finland with a 2 kW solar system would be 1600 kWh and 4000 kWh with a 5 kW solar system.

The annual radiation energy for an optimum surface, estimated annual generation of a 1 kW solar panel system and differences in estimated solar generation between different months in Tampere are presented in the Appendix 1 (Paavola 2013). The estimated levels on monthly solar generation have been calculated with Photovoltaic Geographical Information System, which is a free-of-charge web tool for estimating solar radiation energy and generation of solar power with different panel materials. The system is offered by a common research center of European Commission. (Paavola 2013)

For wind turbines the estimation of decrease of consumption is more difficult to provide because there are not a lot of data on production levels of wind turbines for private consumers. For example, the Finnish Wind Atlas project contains average monthly and annual values of wind speed, potential power production calculated for large wind turbines at heights from 50 m above sea or ground level. The wind turbines of private consumers are usually much smaller. Besides, wind conditions may vary a lot even between short distances.

At the moment the prices of electricity are rather low in Finland which may not motivate most consumers about seriously considering on installing DG on their site. The prices of electricity for small domestic consumers in Nordic countries and in the EU average are presented in Table 3.8.

Table 3.8. *Electricity prices for domestic consumers, annual consumption between 2500 kWh and 5000 kWh, in Nordic countries and the EU average. All taxes and levies included. Semester 1 refers to months from January to June and semester 2 refers to months from July to December. (Eurostat 2014)*

	2011 semester 2	**2012 semester 1**	**2012 semester 2**	**2013 semester 1**	**Average**
	cnt/kWh	**cnt/kWh**	**cnt/kWh**	**cnt/kWh**	**cnt/kWh**
Denmark	29,75	29,97	29,72	30,00	29,86
EU (27 countries)	18,45	18,93	19,67	20,08	19,28
Finland	15,73	15,49	15,59	15,78	15,65
Iceland	-	11,10	11,64	10,53	11,09
Norway	18,70	18,81	17,75	19,09	18,59
Sweden	20,44	20,27	20,83	21,01	20,64

3.2 Others than household consumers

Household consumers are not the only ones who can use Elenia’s energy reporting service. As said earlier, the bound between private customers and enterprise customers in the reporting service is the main fuse size 3x63A. The others than household consumers consist of farms, leisure-time apartments, real estate properties, business apartments and several others. They may have totally different consumption levels and timings. Besides, allocation of a single company’s electricity use is difficult because many companies may exist behind one metering.

Comparison data of household consumers is well comparable as they can be formed into relatively similar groups. The thing is totally different instead with other kind of private customers. Variation in their consumption is much larger so composition of a relevant comparison for them would take more accurate examination. Besides, not much reliable studies on consumption of others than household consumers have been published.

However, as a distribution network operator mainly operating in rural areas, Elenia could offer comparison data for farms even their consumption might be variable. People live in farms anyway and as the basic households are offered comparison data, it could be fair to offer it for people living in farms as well.

Consumption of leisure-time apartments may be extremely different as some of them are used around the year or some at summer time only. They would not be offered comparison data from other customers as it might be too inaccurate.

Comparison data for real-estate properties and business apartments could be offered, if there are similar sites enough in the service. At the moment the number of them is quite small. In Chapter 6 there are more issues on which kind of data could be gathered from them.

The information on other kind of consumption sites is. This kind of sites should be asked the type of a site in prior for possibly being able to find similar sites in the future.

3.3 Requirements for buildings and appliances

Reformed regulation on thermal insulation of buildings came into force on 1st January 2010. Briefly, the new requirements aim at better thermal insulation and heat reclaiming from air-conditioning. The requirements may lead constructors in making more low-energy buildings. The previous requirements on thermal insulation of buildings came into force on 1st January 2008, 1st October 2003 and 1st January 1985. So, the requirements on construction thus have become stricter in the early 21st century. (2002/YMa; 2007/YMa; 2008/YMa)

In 2011 the Ministry of the Environment set a new regulation (2011/2/YMa) on energy efficiency of buildings which came into force on 1st July 2012. The appointment 2.1.3 of the regulation about the coefficients of different energy forms were dispelled in 2013 according to (2013/1/YMa). Besides, some other changes in the regulation were made as well in 2013 and they came into force on 1st June 2013 (2013/5/YMa).

The most remarkable change in the regulation is that the building owners must obtain an energy certificate in conjunction with the building permit proceedings for new buildings. The certificate must be obtained when a building or part is sold or rented out. The certificate will also be required with certain transition times when selling or renting out an old small residential building as well as other buildings. Besides, the energy class of a building must be reported in sales and rental as well. The energy certificate is a tool for comparing buildings’ energy efficiency. Energy class refers to building’s calculatory total energy consumption and it should be presented in the certificate. (Ministry of the Environment 2013) As not referring to building’s actual consumption, it is not a base for rational comparison of consumption sites.

The eco-design directive (2009/125/EC) creates ecological requirements for appliances using energy. It was later amended by the Energy Efficiency Directive (2012/27/EC) in 2012 but only little changes were made to its contents. The target is to get environmental viewpoints and planning of product's life cycle to be integrated into product's planning period. The directive is a general agreement which does not affect directly to product manufacturers. However, the Commission has set regulations for appliance groups, known as eco-design requirements. For example requirements in planning of standby-power, televisions and refrigerators have been done. (The Federation of Finnish Technology Industries 2013)

Also the EED includes commitments for building renovation in Article 4. It states that the EU member states shall establish a long-term strategy for mobilizing investment in the renovation of the national stock of residential and commercial buildings. A first version of the strategy shall be published by 30th April 2014.

3.4 Motivation to decrease consumption

Consumers' increased knowledge about energy issues enables more effective use of energy. Finnish Energy Industries stated in 2008 (Finnish Energy Industries 2008) that communication based on examined facts are more powerful than prohibitions and regulations. Attitudes and opinions have turned into more ecological way and with right communications significant improvement in energy efficiency can be achieved.

According to a research made by Motiva Oy in 2009, the biggest factor that motivates most to decrease energy consumption is money (Motiva Oy 2009a). Monetary savings are also stated as the most ruling factor for consumers' interest towards DR in survey done by University of Vaasa and ABB in 2013 (University of Vaasa & ABB 2013). Thus, it should be brought out clearly how changing consumption habits would change the costs. There are a lot of people who do not know their annual consumption or how much the electricity price could increase before it would have an effect on their consumption. According to Motiva's 2009 research, 68 % of examined consumers could not state their annual consumption and 43 % could not tell their annual electricity bill. Besides, 50 % - 59 % of the answerers could not tell amount of increased price or relative growth that would affect on habitual changes.

Second biggest factor in Motiva's research were environmental issues. Carbon dioxide emissions could be used to attract customers concerned on natural issues. CO_2-emissions can be presented by using an average CO_2 emission coefficient of electricity generation in Finland. The CO_2 emission coefficient has been around 150 g/kWh in Finland during last years (Finnish Energy Industries 2014). Finnish Energy Industries release regularly a publication about the CO_2-emissions of electricity generation in Finland. Figure 3.5 presents the generated CO_2-emissions of electricity generation in g/kWh –unit in Finland over June 2011 – February 2014. The figure excludes emissions from biomass combustion.

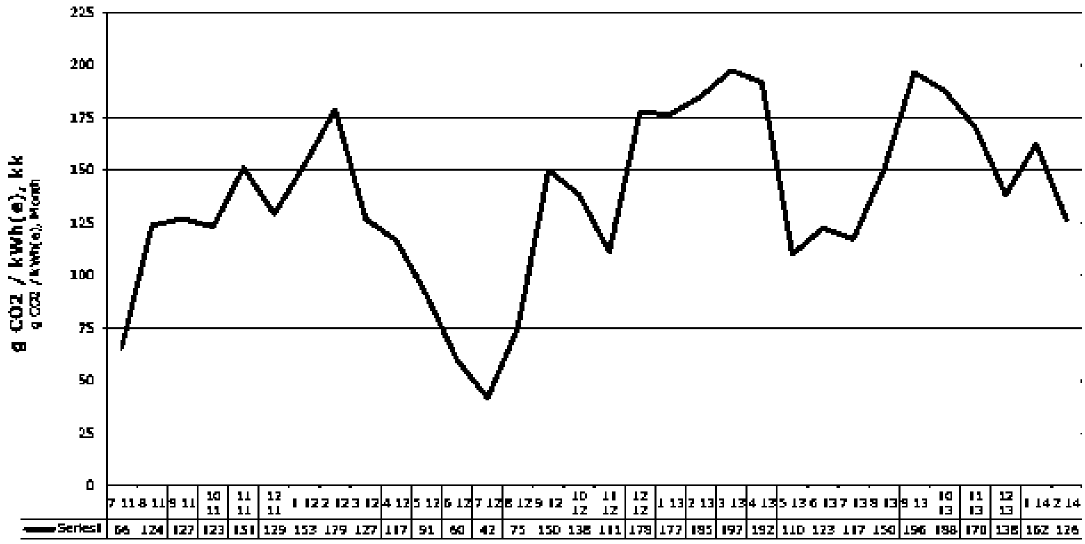

Figure 3.5. *CO_2-emissions of electricity generation in Finland over July 2011 - February 2014. Emissions from biomass combustion are excluded. (Finnish Energy Industries 2014)*

Households' consumption can be affected by increasing examined on-time data on their energy use. For instance, Darby has stated that improved feedback may reduce consumption up to 20 per cent (Darby 2006). The data must have a form that benefits consumers and is easy to understand so that consumers can do actions and change their consumption habits. Energy companies have a key role here as they have accurate data on energy volumes and also timings of consumption due to smart meters. (Finnish Energy Industries 2008)

3.4.1 Definition of stimulating consumption feedback

Electricity use of households is usually based on routinized or habitual behavior. People may switch on lights or electric heating without thinking or they use a washing machine always with a same program. Habitual behavior is practical because it spares time and effort of decision-making on issues that occur regularly and for which they have once learned a way to solve them. Thinking of reducing electricity consumption, habits on wasting electricity must be broken up somehow. (Fischer 2008)

A process for changing habits is presented in Figure 3.6. Firstly, a consumer must realize the problem. Secondly, a person must understand that she has possibilities to influence her behavior and its outcomes. Thirdly, a consumer must start weighing and evaluating different motives in order to reach a decision on how to act. (Fischer 2008)

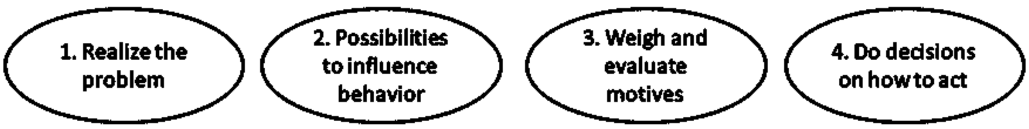

Figure 3.6. *A process for changing habits.*

Feedback is most effective if it successfully captures the consumer's attention, draws a close link between certain actions and their effects and activates various motives that may appeal to different consumer groups, such as monetary savings, resource conservation, reduction of emissions, competition to similar consumers and others. Thus, tools of feedback on electricity consumption should contain diverse but simple attributes that consumers would be able to understand and realize there are possibilities to reduce consumption. Consumers can be assisted to detect possibilities to influence their electricity consumption with appliance-specific breakdown and electricity saving tips. For example, if a consumer notices the reasons behind high consumption levels and the change on consumption behavior is easy and cost-effective to carry out, she could act to reduce consumption.

Many studies have shown that proper feedback on consumption stimulates electricity savings and reduces the costs. Savings have been found from 1,1 % to over 20 % per household. Usual savings are between 5 % and 12 %. (Fischer 2008; Karjalainen 2011)

It has long been clear that the way information is presented is crucial for mode of presentation. This is because the information needs to capture the attention and be understood before it can become effective. Roberts and Baker (Roberts & Baker 2003) suggest that the form of presentation as a combination of text, diagrams and tables is more effective than single-format presentations.

3.4.2 Comparison data and advices on energy efficiency

Consumers would like to get sufficient comparison data from their consumption and improved advice on more effective energy use. According to the survey about feedback on consumption data and energy saving tips made by Motiva Oy in 2009, 56 % of the total 1000 repliers thought they do not get comparison data sufficiently about decent energy consumption in their occasion. According to the repliers, the most important factors for saving energy are billing based on actualized consumption, information on more effective energy use and comparison data to consumer's own consumption. Besides, the survey states that three weakest factors of energy companies are comparison data to other households, advice on personal energy efficiency and information for enhancing energy use. (Motiva Oy 2009a)

Figure 3.7 represents the ways of comparison data that would best enhance frugality or in other words, more effective energy use.

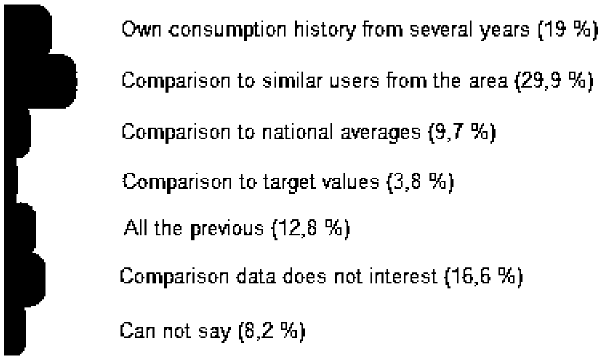

Figure 3.7. *Comparison data that would best enhance frugality. (Motiva Oy 2009a)*

Roberts and Baker state that people are motivated to reduce consumption if comparison shows that their consumption has been *"above average for a group they perceive to be relevant for comparison"* (Roberts & Baker 2003). Also Fischer states that when comparing consumption to other consumers, high-consuming users are stimulated to conserve energy but low-consuming users instead are not as stimulated (Fischer 2008).

It may be challenging to get most of the consumers to share their data from consumption sites as, according to the Motiva's survey, only 43,1 % of the repliers told they could definitely give data for getting better comparison data whereas 44,6 % told they would not. On the other hand, the survey was made as a phone interview so the repliers might not have had a right clue about the usefulness of the comparison data.

Consumers having bigger needs for new services and products aiming at more effective electricity use were examined in the research published by National Consumer Research Centre of Finland in 2012. Those pioneer consumers usually have bigger consumption than others or they are mostly due to natural reasons more interested on reducing consumption. Their needs and wills were examined as they have more knowledge on electricity consumption or they had already been installed new heating systems or house automation so they are more interested in services of Smart-Grid technology. (Heiskanen et al. 2012)

Pioneer consumers were most attracted by advanced electricity consumption reporting and monitoring services and services concerning on own generation of renewable energy sources. Also services related to remote-controlling interested part of the consumers. In terms of DR, the service based on automatic load management seems more acceptable than pricing based on prices on electricity markets. The storage of electricity into the car's battery felt remote among pioneers, but raised interest among some of them. (Heiskanen et al. 2012)

4 CURRENT CONSUMPTION REPORTING SERVICE OF ELENIA OY

Feedback on electricity consumption for consumers is important because electricity is invisible, untouchable and it is used indirectly via various appliances and services. Electricity is regarded as a necessary but unspectacular product of which it is hardly to be proud of. But still, the bills have to be paid. Kempton and Layne have compared consuming electricity to shopping in a grocery store in which no individual item has a price marking. Consumer receives a monthly bill on an aggregate price for food consumption but she has no idea which items are expensive, which could be cheaper, when the items were bought, whether her bills are relatively high or low or whether her actions had any effect. (Kempton & Layne 1994)

Electricity consumption reporting service brings transparency to a consumer's consumption and billing. Consumers might even change their consumption behavior if they would have proper feedback on their electricity use. Elenia Oy has offered its customers the online reporting service on their electricity use since 2010. Current attributes of the service and the results from a customer inquiry concerning the development of the service are presented in this Chapter.

4.1 Online services of Elenia

Elenia's free-of-charge online services are available for customers whose consumption site is locating in the company's network. Main purpose of the service is the improvement of the customer service. There are two different service channels: a web-based *Elenia Minun Sivuni* and a mobile phone -based *Elenia Mukana*.

Elenia Minun Sivuni is the main online service where customers are able to handle their contract issues, billing, fault reporting and to view their electricity consumption with the energy reporting service –attribute.

Elenia Mukana is a free-downloadable smartphone application for customers to mainly view their consumption. It acts also as an easy channel for customers to report for a network fault or to send a feedback or contact request to a company. Customer can for instance send a picture on a site of fault or threatening fault.

4.1.1 The energy reporting attribute

The energy reporting service was established in Elenia's online services in May 2010. With the attribute, customers are able to view electricity consumption data from the beginning of 2010. Due to systems of data transfer, it usually takes two days for the latest consumption data to be shown in the service. The service can show electricity consumption at an hourly accuracy. The consumption data is applied straight from the MDMS. In this thesis only the energy reporting service for private customers is examined. Consumption data for enterprise customers is presented in other consumption reporting attribute in the service.

Figure 4.1 shows the current appearance of the energy reporting service. A customer is able to change a starting date of the analysis, a desired time period and a display level of consumption, and whether to view the data as a graph or a table or as consumption units or euros. A customer can also decide whether or not to view outdoor temperature and comparison data. Outdoor temperature is presented from the measurement station that corresponds to the comparison locality which a customer has selected. Temperature is shown as a red curve and a comparison data is shown as a yellow curve. Comparison data is analyzed in Chapter 4.1.2. Customer's own consumption is presented as columns.

Figure 4.1. *Consumption graph in the energy reporting service. An example consumption site presented.*

In the service customers can enter certain attributes from their consumption sites so that the service can display the corresponding outdoor temperature and comparison data from similar customers. The attributes that are possible to be given are dealt in the Chapter 4.1.2 as they affect on formation of comparison data.

A month is the longest time period and a day is the longest display level to be showed in a graph. Longer periods and display levels are needed to be showed as customers would like to examine their long-time consumption and compare different months to each other with a one glimpse. Also value of total consumption of a selected time period should be presented along the graph. Now the total consumption value of a selected time period is viewable only if a customer downloads the consumption data to an excel file.

A first version of Elenia Mukana –smartphone application was launched in December 2012. The appearances of the current energy reporting attribute of the application are presented in Figure 4.2. The right-handed appearance 4.2 b) shows up by clicking the button *Consumption data* in the left-handed appearance 4.2 a).

a) b)

Figure 4.2. *The appearances of energy reporting attribute of Elenia Mukana - application. The a) is the front screen of the application and b) is the detailed screen on consumption data.*

The front screen contains brief data on realized consumption and actual costs from the previous full month and the comparison period. The customer has needed to enter the tariff data for seeing the costs. The yellow arrow represents the brief comparison between the previous full month and the comparison period. The detailed consumption data shows consumption either in kWh or euros. In Figure 4.2 the customer has a two-time tariff so the white column represents the day-time consumption and the blue column shows the night-time consumption. For customers having the one-time tariff the blue column presents the total consumption. The red curve represents the temperature data and yellow curve shows the consumption of a comparison group. Other properties are quite similar compared to ones in Figure 4.1, only the appearance is different.

4.1.2 Comparison data

Possibility for comparison of electricity consumption was established in the service in November 2011. Consumption sites in which at least the needed attributes were entered were attached in some of nine comparison groups after three main heating modes and three comparison localities. At that time there were 9 006 such consumption sites and they comprised the nine comparison groups. Formation of the groups is presented in Figure 4.3. Because the comparison groups were done static and they have not been updated, the groups still consist of the same consumption sites although the amount users has more than doubled until December 2013. Besides, a main heating type in some of the original consumption sites might have been changed and thus they would not belong to a certain group anymore.

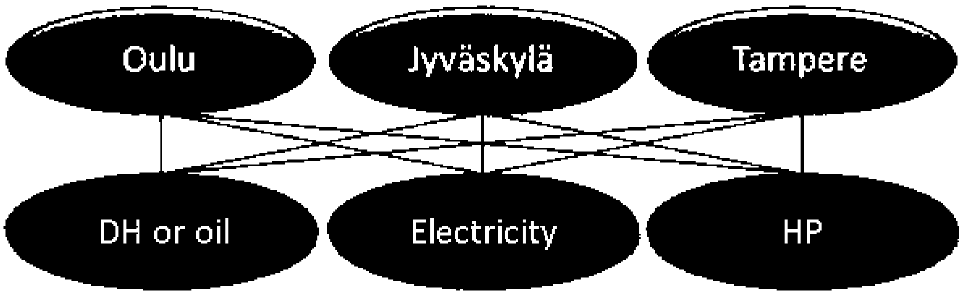

Figure 4.3*. Current comparison groups of the service, 9 groups in total. DH means district heating and HP refers to heat pump.*

Any customer who has signed in for the service and has entered at least her consumption locality and main heating mode can compare her consumption in the service. The service recognizes which comparison group has the similar attributes as a customer has entered. Comparison data to be shown is calculated as an average values for a selected time period from all the consumption sites that belong to a consumption group in question.

Even though there are only two determining attributes at the moment, customers might have entered all the following attributes from their site in the service. These attributes were selected in the service in 2011 as they might be used in service development in future.

- *A type of a building*
- *Surface area and volume of a building*
- *A main heating mode*
- *A construction year*
- *Number of residents*
- *Comparison locality*
- *Tariff prices of electricity supply (basic charge and supply charge)*

A customer can select the most suitable option for a type of a building from detached house, apartment in an apartment building, row house, semi-detached house or leisure-time apartment. A main heating mode is selected from traditional electric heating, accumulating electric heating, district heating, oil heating, air heat pump or ground-source heat pump. Electric heating and accumulating electric heating are regarded together and, in turn, ground-source heat pumps are regarded together with air heat pumps, as all the options are not taken into account in comparison groups as seen in Figure 4.3. Comparison locality is chosen from many Finnish localities but only three of them really matter according to Figure 4.3. Surface area, volume, construction year, number of residents and tariff prices of electricity supply are marked as numbers.

The attributes that are entered in the service are stored to a server of Elenia's partner company. Average values for a consumption of the comparison groups are calculated in the MDMS. If a customer wants to see the comparison data, the reporting service sends a request to the partner company's server which again sends a request to the MDMS to show the previously calculated average values of a corresponding comparison group for a selected time period. Then the MDMS sends the results to the reporting service which presents them to a customer in a same graph as her own consumption.

There are a lot of practical problems in comparison at the moment. Firstly, the number of comparison groups is too little as many important consumption explaining factors have not been taken into account. Comparison data may not be relevant to several consumption sites. Secondly, the service classifies customers only in accordance with households. There are no classification for farms, real estate properties et cetera, which may have totally different consumption profiles and levels than households. Thirdly, the comparison groups have not been updated so the original sites in the groups might have become irrelevant. Fourthly, no comparison data from previous time periods, for instance from previous years or months, is possible to view in a same graph. Comparing consumption between different years would be stimulating and it is also wished by customers (Vattenfall Verkko Oy 2011).

4.2 Customers' opinions on the reporting service

As the service is done for the customers it is important to research their opinions and wishes concerning the service and especially the comparison data. Many single feedbacks concerning the service have been given by the users. Feedbacks have mainly concerned usability of the service and billing details. Feedbacks concerning possibility for observing longer than monthly time periods in consumption and for comparing of a customer's own consumption among different years have also been given. Also alarms due to abnormal consumption levels have been hoped.

Vattenfall Verkko Oy, a preceding electricity distribution company to Elenia Oy did a customer inquiry for the users of the energy reporting service in May 2011. First five thousand users of the energy reporting service were sent an inquiry by email and 1241 customers answered it. The inquiry was basically made to define the needs for future service development.

Figure 4.4 shows portions on things that the customers were monitoring in the energy reporting service. Customers were able to choose many options. Monthly variation in consumption and peaks in electricity use were regarded the most popular things as over two thirds of the answerers picked them. Monitoring of hourly variation and temperature effect in consumption were picked by around half of the answerers.

		Amount	Portion	20%	40%	60%	80%	100%
1.	Monthly variation in consumption	909	77,36%					
2.	Hourly variation in consumption	682	58,04%					
3.	Peaks in electricity use, i.e. saunas, machines, accumulating electric heating	825	70,21%					
4.	Temperature effect on consumption	618	52,60%					
5.	Shifting consumption data to excel	238	20,26%					

Figure 4.4. *Things that customers monitor in the energy reporting service (given options). (Vattenfall Verkko Oy 2011)*

Figure 4.5 presents portions for pre-selected things that the users hoped to find in the service. Comparison data was the most popular one by almost half of the answerers. It is notable that comparison data was not available in the service at the time of the inquiry as it was established there later that year. Typical consumption level of various appliances and reasons for deflections in consumption were the second popular wishes for the service development. Around one fourth of the customers hoped reports to the email, information on power outages and energy saving tips to be available.

		Amount	Portion	20%	40%	60%	80%	100%
1.	Energy saving tips	238	22,00%					
2.	Reasons for deflections in consumption	347	32,07%					
3.	Typical consumptions of various appliances	453	41,87%					
4.	Comparison data in electricity use	517	47,78%					
5.	A calculator of the best network tariff	193	17,84%					
6.	Automatic alarm in exceeding consumption limits	148	13,68%					
7.	Reports straight to the e-mail	312	28,84%					
8.	Information about power outages	272	25,14%					
9.	Something else	96	8,87%					

Figure 4.5. *Information hoped to be found in the service. (Vattenfall Verkko Oy 2011)*

As seen clearly, most of the hopes are regarded as automatic things, in other words as things that a customer gets the information automatically from the service for example to her email or mobile phone. According to the results and trends in development of smart grids and DR, they should be considered as potential ideas in service development. For example, Elenia Oy has already a service that informs customers on power outages.

5 DEVELOPMENT OF ATTRIBUTES OF FEEDBACK

In this Chapter, the possible tools and attributes that could be harnessed in the service are presented firstly. Secondly, the suggestions on how the data for classification should be gathered are presented. For being able to compare similar electricity consumers properly they need to be classified to different groups with similar factors. Different methods for creating comparison groups are defined thirdly. At last, the temperature correction for comparing consumption from different years is presented.

Development of feedback on consumption and comparison are based on wills of Elenia personnel, supervisors and examiners through interviews and meetings, results of customer feedbacks and inquiries presented in previous chapters, publications on consumption feedback and writers own vision.

5.1 Tools and attributes for improved feedback

Feedback may be improved in various ways. Possibilities include increasing the frequency of feedback, improving the visual design, adding further information, for example longer time series, comparisons or information about environmental impact, and providing a time-, room- or application-specific breakdown. (Fischer 2008)

Best types of feedback, according to Fischer, are

- *Designs that provide computerized feedback, offering multiple feedback options at the user's choice (e.g., consumption over various time periods, comparisons and additional information like environmental impact or energy-saving tips).*
- *Designs that used an interactive element that engages households – through computerized feedback or through required activities like self-feedback or self-meter reading.*
- *Designs that provide detailed, appliance-specific breakdowns*
- *Designs that give feedback very often (daily or even more often)*

Thus, the following sub-chapters contain the suggested tools and attributes to be obtained in the online electricity consumption reporting service of Elenia Oy.

5.1.1 Frequency and duration

According to Fischer, feedback is more effective the more quickly it is given. Direct feedback would have an effect on understanding the relation between an action and consumption, and increase consciousness about the consequences of different actions. (Fischer 2008) It is very desirable to get the consumption data presented to a consumer as soon as possible, for example with a delay of one day or even one hour. The best impact would be achieved with real-time monitoring systems, but as the consumption is measured with an hourly accuracy and stored into MDMS daily, it is impossible to offer real-time consumption data without consumption monitoring systems at home.

In addition, feedback from a long time period is desirable as habitual effects would likely to be noticed and further, persistent changes on consumption may be achieved. (Fischer 2008) At least yearly consumption and comparison between different years should be presented.

5.1.2 Content of feedback

The most typical content of feedback has traditionally been providing feedback on consumption units, mostly kWh. Feedback could also be presented based on costs or on environmental impacts of consumption which could be given on CO_2-emissions from electricity generation. Different contents activate different consumers, motives and social norms, and it is difficult to state which motives and norms would have the strongest consumption effects in different target groups (Fischer 2008).

Feedback presented in kWh is justifiable as consumption is measured with it. It is really usable for comparing consumption between different consumers. Instead, monetary costs are not very good for comparing customers as costs depend on consumption and tariffs. However, potential monetary savings can be brought out to a customer by telling how big savings could be achieved with one's own tariff and consumption level of a comparison group. Because the distribution company may not know the tariff of electricity supply, customers should enter it by themselves in the service. An occasional default value for tariff of supply could be used if it has not been entered.

As stated in Chapter 3.4, monetary savings are usually the best reason for decreasing consumption. However, probable savings may be low if prices of electricity are low or consumption is low. In Finland, the prices of electricity are lower than in average in the EU, which was seen in Table 3.8. Thus, the savings should be brought out over a long time period to get customers attracted by persistent effects on decrease of electricity use. According to Heiskanen et al. (Heiskanen et al. 2012) customers are hoping for data on monetary benefits with example calculations. It is seen in Figures 5.3 and 5.4 how the example calculations could be provided.

CO_2-emissions could be presented by using the CO_2 emission coefficient which was dealt in Chapter 3.4. At the moment the coefficient is around 150 g/kWh in Finland.

5.1.3 Interactive tools and additional information

Feedback could be combined with tools that increase consciousness and interactivity, and provide links between actions and consumption levels. The suggested tools are

- *Outdoor temperature*
- *Goal setting*
- *Alarms*
- *Markings*
- *Typical consumption levels of appliances*
- *Energy saving tips*
- *Other messages*

Outdoor temperature could easily show customer the dependency between outdoor temperature and consumption. It should be presented from the closest measurement station possible.

Goal setting, or setting target of consumption, gives customer a possibility to set motivating levels on consumption for each month. Consumption goals for daily accuracy may not be recommended as consumption varies a lot between different days. Customer could define the targets manually or as a relative increase or decrease compared to consumption on same months from previous year. When defining the targets, the increased or decreased values on kWh, euros and CO_2-emissions could be presented to a customer.

Alarms would let customer know about unusual consumption levels. Alarms could be sent to a customer via email or text message. Three types of alarms could be provided, which are alarms on consumption exceeding the monthly target, consumption about to exceed the monthly target and consumption being too low.

Firstly, if consumption has exceeded the monthly target, a customer would be notified. Secondly, a customer would be notified if more than half from the defined target has been consumed until midway of a month. Then consumption could be tried to decrease during the rest of the month. Thirdly, if consumption was too low during certain time period, a customer would be alarmed. This might happen due to unordinary action of a certain appliance or a heating system.

Markings would also increase the interactivity and interest towards the service. For example, after noticing a high peak a customer could enter the reason for it.

Typical consumption levels of appliances could be provided with tables and graphs. Typical consumption levels from different types of apartments examined in Adato's research are collected in the Appendix 2 (Adato Energia Oy 2013). As AMR-devices do not classify the consumption based on where the electricity has used, more accurate appliance-specific breakdown cannot be provided.

Energy saving tips could be classified in different sectors, such as ones presented in Tables 3.2 and 3.7. Thus, a customer could look for tips that he or she finds relevant. Otherwise, links to reliable websites on energy saving tips could be provided at least.

In addition, the use of the service may forget as well. The last login date could be stored into the database where the consumption-explaining factors are stored as well. Notifications could be sent to customers who have not used the service for six months for example. Thus, customers could be motivated to monitor their consumption by reminding about the benefits on reduce of consumption.

5.1.4 Actualized consumption

Customers can follow their actualized consumption with this attribute. The outfit of the attribute can be chosen as a graph or a table. Graph could be downloaded to a customer's computer as a PDF-file and table as a table file.

Figure 5.1 presents the possible features of the attribute. If compared to current features in Elenia's reporting service, the biggest changes are larger time scale and possibility to use interactive tools like goal setting and consumption markings. Besides, similar tool for viewing consumption data and monetary costs quickly as in mobile phone application Elenia Mukana, presented in Figure 4.2 a) is desirable. In addition to that, also CO_2-emissions would be brought out.

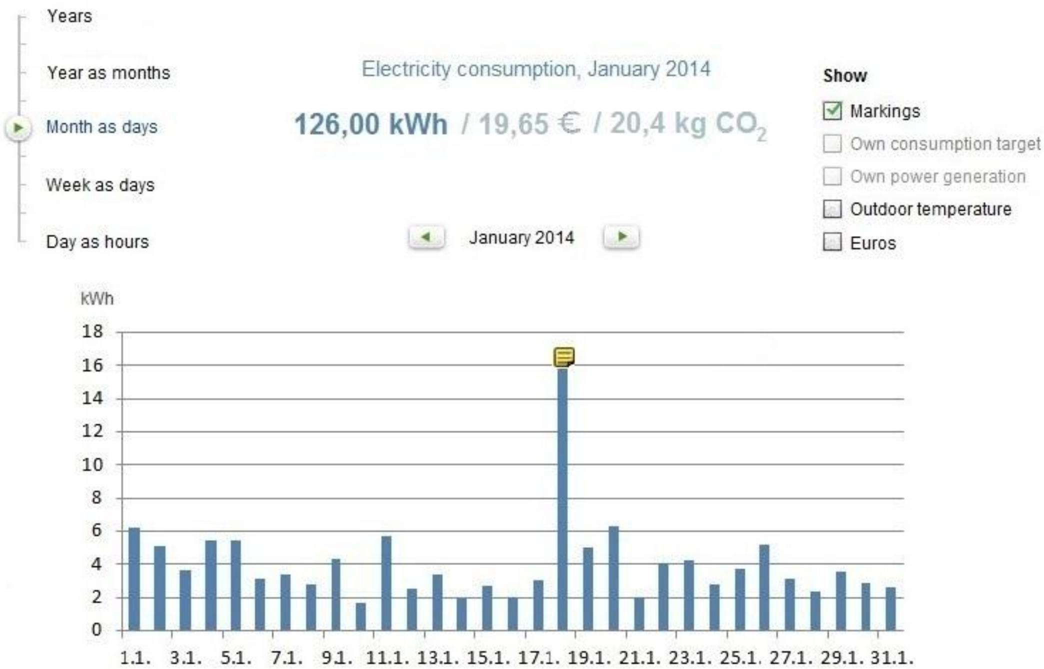

Figure 5.1. *Possible features on actualized consumption.*

Monetary costs could be brought out with the tool above the graph and like currently, by clicking the field *Euros* which separates costs on distribution, supply and taxes on columns. CO_2-emissions are calculated, according to Figure 3.5, with 162 g of CO_2 per 1 kWh of electricity generated.

Markings could be showed as signs placed on certain hours. Own consumption target could be brought out as a line, although it is not selectable in the figure as the targets are not determined by daily accuracy. When monitoring consumption with monthly accuracy, the target would be selectable. Outdoor temperature can be showed like currently, as a line. Production of own generation could be showed with a different color in the columns. Like explained in Chapter 3.1.8, it would show the customer the amount of electricity that the generation has produced into the grid. Thus, it would be selectable only for customers who have generation with such a possibility. The information on that is got from the CRM software as told in Chapter 3.1.8.

5.1.5 Comparisons

Comparisons may stimulate specific motives for energy conservation, for example a sense of competition and ambition. They also create transparency on whether consumption in a certain period is out of the normal, thereby capturing the consumer's attention, alerting for a potential problem, activating in search for reasons and redressing the problems. (Fischer 2008)

There have been two basic types of comparisons on electricity consumption in literature: historic comparison and normative comparison. Historic comparison presents consumer's consumption from a selected time period and consumption from previous years from the corresponding period. Normative comparison refers to comparing consumption to that of other households, for example national or regional averages, households in the neighborhood or households that are in some way similar. (Fischer 2008)

In addition to historic and normative comparisons, a comparison to selected types of households is presented in this Thesis. This type of comparison may let a consumer notice how consumption levels are different due to different factors. For example, benefits due to different heating system would be noticed and motives for investing on ancillary heating systems could strengthen.

Historic comparison

Figure 5.2 presents the possible features of historic consumption. A customer is able to view the data from the corresponding periods from different years. The CO_2-emissions are calculated according to the corresponding values in Figure 3.5.

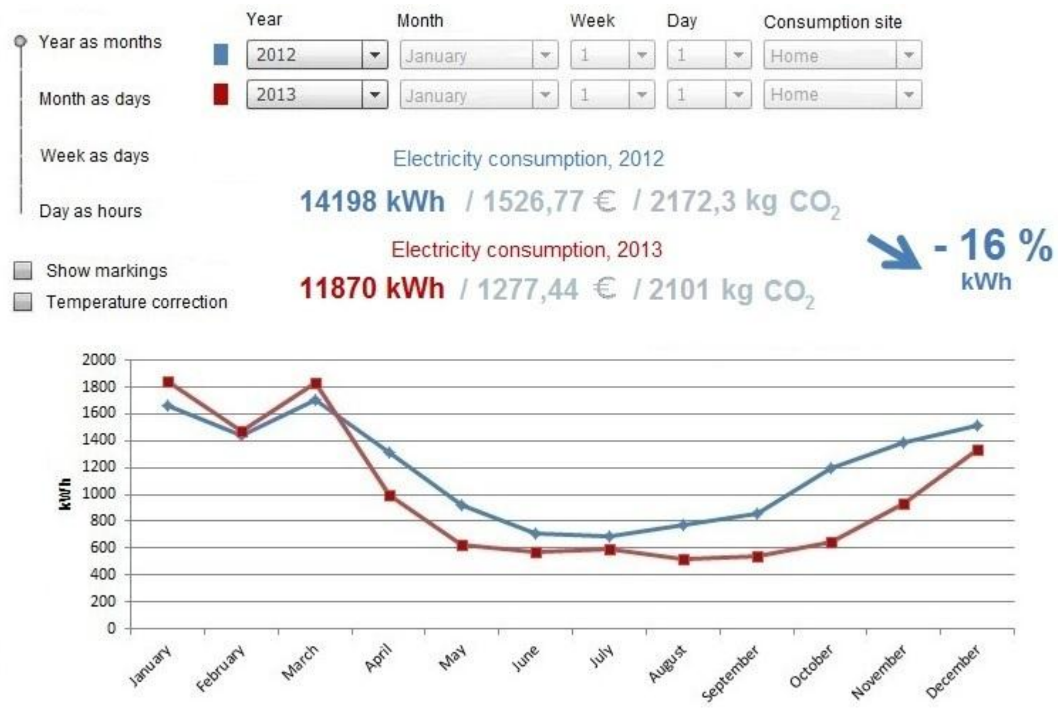

***Figure 5.2.** Possible features on historic comparison.*

The similar tool as in Figure 5.1 on presenting consumption data quickly on different units is desirable. The consumption change could be presented by an arrow, seen on the right-hand side in the figure. The outfit of the attribute can be chosen as a graph or a table. Besides, a consumer could be given a chance to view the data with or without temperature correction. By temperature correction, a consumer can get an insight on consumption levels with the same monthly outdoor temperatures. Temperature correction is dealt in Chapter 5.4. Markings could explain customer the reasons behind abnormal consumption.

Normative comparison

The normative comparison can be done according to the relatively similar consumption-explaining factors. They will present the regional consumption data between similar households. In this thesis the regional consumption data is achieved by dividing the Elenia's network in three sectors according to the Chapter 3.1.4. National averages are difficult to carry out without temperature correction in Finland as the temperature differs a lot. If the values were temperature corrected, they would need to be corrected to the same temperature as the user has had. That will be difficult as more measurement points would be needed to get sufficient results. If the amount of measurement points is large, regional consumption data could be replaced by the national ones.

Figure 5.3 presents possible outfit of this attribute. Blue columns present the actualized consumption of a customer. The maximum, average and minimum data of the comparison group are presented as lines.

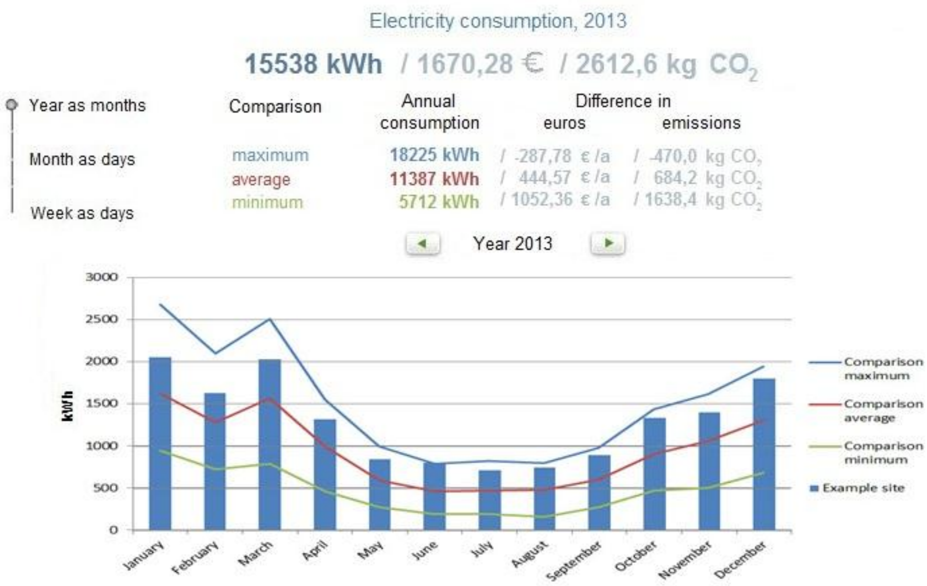

Figure 5.3. *Possible features on comparison to similar households.*

As said earlier in Chapter 3.4.2, using only average consumption of the comparison group, the people may not be motivated on reducing consumption if their consumption is below the average (Roberts & Baker 2003; Fischer 2008). That problem could be solved by giving them different ‘steps’ to achieve. Steps refer to lines of comparison maximum, average and minimum. The maximum and minimum curves are shown from the top and bottom consumption values for each unit of time from the consumption sites that belong to the comparison group. As there may be unusual consumption in both sides, five per cents from top and bottom consumptions could be eliminated.

The time scale could be used as in Figure 5.2 or in Figure 5.3, depending on whether customers are liked to get comparison data by an hourly accuracy or not. There is always hourly variation in consumption and that may result on comparison curve becoming flattened as the peaks in consumption occur at different hours between separate consumers. On the other hand, if the maximum and minimum curves are calculated as explained, the variations in hourly consumption would be shown. Only the average curve might be flattened.

The differences in euros and emissions between the own consumption and the comparison lines could be presented as in Figure 5.3. Thus, a clear message on the savings would be presented. The monetary savings are calculated by using the customer’s own tariff and the difference between consumptions of each comparison line and the customer.

Comparison to different types of households

Figure 5.4 presents a draft from the possible features to be harnessed when comparing different types of households. According to Heiskanen et al. (Heiskanen et al. 2012) the pioneer consumers would like to get comparison data on different kind of households. The differences to comparison groups are presented similarly as in previous figure.

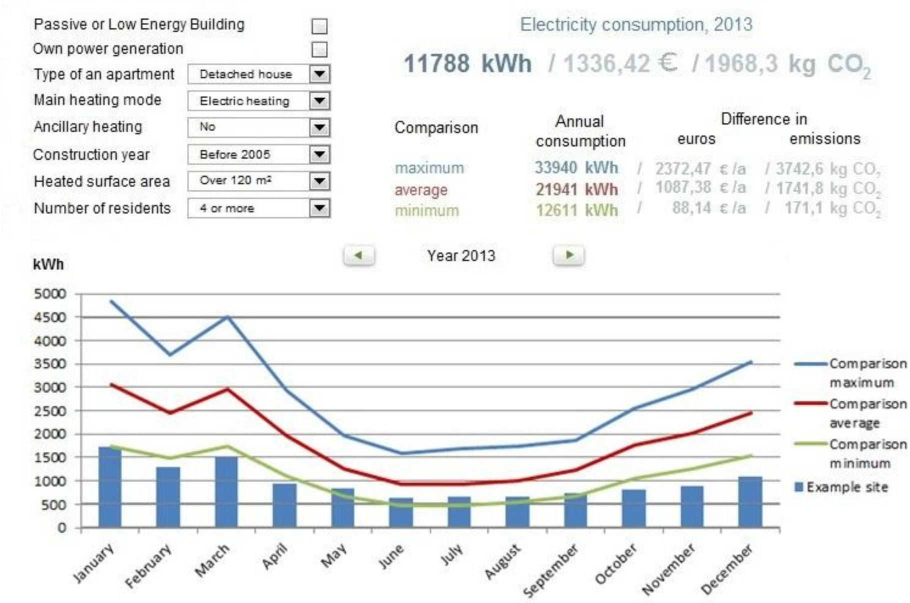

Figure 5.4. *Comparison to different types of households*

The factors that change the comparison graph or values are listed above the graph. For example, now the consumer of the example site has district heating as an own main heating mode, but *Electric heating* has been selected for a main heating mode to be examined. The result is that the own consumption seems to be distinctly smaller than the consumption of sites with electric heating. It depends on the structure of customer classification on how the factors and the options would be determined and brought out. Customer classification is dealt in Chapter 5.4.

By choosing the option *Passive or Low Energy Building*, consumer will view the consumption data from those sites. By choosing *Own power generation* a customer would be provided the decrease of consumption in the columns by adding the data on the regional average generation there. The decrease could be showed with a different color on the columns.

5.2 Data gathering

For being able to classify consumption sites into certain groups, valid data needs to be gathered from them. Until now, the users of the service might have entered some consumption-explaining factors from their site in the reporting service. They have needed to enter at least comparison locality and main heating mode to get comparison data, and tariff prices of electricity supply for monitoring the monetary costs.

The challenge when customers enter the data by themselves is to get customers to give truthful data from their consumption sites. For example, consumers living in an apartment building do not know their main heating mode as well as people living in other type of buildings. Another challenge is to get them to give data at all. According to the Motiva Oy’s research, 44,6 % of the total 1000 customers answering told they are not willing to give information of their household and behavior, even if they could get more accurate comparison data (Motiva Oy 2009a).

Population Register Center of Finland has gathered vast data on over three million buildings and almost three million households in Finland in their database of *"Real estate information"*. It has been collected as a co-operation with the cadastral register of the National Land Survey of Finland. For example, information on size of a building, construction year, size of apartments, main heating mode and residents are registered in the database. However, the access in a database is for research use and it is not free. Besides, according to Adato Energia Oy's research, part of changes of main heating mode are left without marking in the register and for instance, the portion of oil heating is too big and the portion of district heating is too small in the register. (Adato Energia Oy 2013) In addition, it might cause questions among customers on how the data already exists there even they have not entered anything in the service.

Table 5.1 shows the data on consumption-explaining factors that are needed to gather for creating the proper comparison groups and for future service development. The two first factors would have to be selected before the others because of making sure the customers pay attention enough on selecting the options correctly.

Table 5.1. *The data on consumption-explaining factors that are needed to gather for forming the comparison groups.*

Factors needed	Options
Type of a consumption site	*Household, Farm, Leisure-time apartment, Real estate property, Business apartment, Others*
Construction quality of a building	*Normal, Low energy, Passive energy, Zero energy, Plus energy*
Type of an apartment	*Detached, Semi-detached, Row house, Apartment in apartment building*
Main heating mode	*Common heating with housing cooperative, Traditional electric, Accumulating electric, District heating, Geothermal, Oil, Wood, Pellet, Gas, Air heat*
Ancillary heating	*Nothing, Wood, Air heat, Other electric, Wood + air heat, Wood + other electric, wood + air heat + other electric*
Heated surface area	*Selectable*
Construction year	*Selectable*
Number of residents	*Selectable*
Own power generation	*Solar, Wind, Other, Nothing*

The options are selected as above because they are the most common ones in households in Finland and they sort out the households clearly. The options for *Type of a con-*

sumption site are selected as above as they are the most common sites of private customers. By selecting *Others,* customers could write manually the purpose of the site.

The options for *Construction quality of a building* are meant for separating households with clearly different construction techniques or properties for heat insulation.

In different types of households the electricity consumption is measured in different ways: in many housing cooperatives the heating is done by a common central heating and households pay for the heating in their maintenance charge. This is a common way in most not-electric-heated apartment buildings and row houses in which the AMR-device of a single household measures only the use of appliances. Also electricity for warm water is mainly measured commonly there. Thus, such row houses and apartments in apartment buildings can be mixed for comparison. In addition, detached and semi-detached houses can be mixed as there the heating is mainly measured one by one.

Households that consume different amounts of electricity due to different heating systems are separated by the options *Main heating mode* and *Ancillary heating*. Option *Common heating with housing cooperative* could decrease the erroneous selections, as people especially in apartments in apartment buildings may not know their heating mode.

Heated surface area, *Construction year* and *Number of residents* can be selected by a user. Depending on customer classification, households are categorized into groups with the similar factors. Information on *Own power generation* could be used in the future. The nominal power of the appliance could be asked as well.

5.3 Customer classification

Customer classification needs to be done for being able to give comparison data from similar or selected types of customers. From the diverse group of private customers, households having normal or traditional construction attributes should be prioritized for offering the comparison data as it is the largest subgroup of them. It can also be offered for households with modern construction techniques, farms and real-estate properties if the amount of such of users increases in the future.

Instead, leisure-time apartments, business apartments and other sites are more difficult to be given reliable data from similar sites because consumption in sites of those subgroups is really variable.

Two different methods for finding proper comparison groups are presented in the following sub-chapters. The methods are grouping and clustering.

5.3.1 Grouping

The idea of this method is to create certain number of comparison groups, so that customers with relatively similar factors belong to the same group. The number of groups cannot be big, as there may otherwise be not sites enough in certain groups. The consumption sites are classified in different groups according to the consumption-explaining factors that are stored in a database which communicates with the MDMS.

Formations of comparison groups are presented in Tables 5.2, 5.3 and 5.4. Table 5.2 presents the formation of comparison groups of households with normal construction quality. The reasons for formations are presented after every Table.

Table 5.2. *Formation of comparison groups of households with normal construction quality. Total amount of groups is 342.*

	A	**B**	**C**	**D**	**E**
Type of a site	Household	Household	Household	Household	Household
Construction quality	Normal	Normal	Normal	Normal	Normal
Type of an apartment	Apartment building and row house	Detached and semi-detached	Detached and semi-detached	Detached and semi-detached	All together
Main heating mode	Common, DH, oil, gas, wood, pellets, geothermal and air heat	DH, oil, gas, wood and pellets	Air heat pumps	Geothermal	Traditional and accumu-lating electric heating
Location	1	1	3	3	3
Ancillary	3	3	2	3	3
Area	3	3	3	3	3
Residents	2	2	2	2	2
Year	2	2	2	2	2
Total	36	36	54	108	108

Firstly, the classification according to types of consumption sites is done according to the options in Table 5.1. Secondly, normal houses are separated from differently built houses. In future, when the number of others than normal houses increases, they can be classified from each other.

Thirdly, classification according to type of an apartment can be done in two groups as explained in Chapter 5.2: apartment buildings and row houses comprise the other group, and detached and semi-detached houses comprise the other.

Fourthly, main heating mode classifies apartment buildings and row houses in two groups: in column A are the ones where the main heating is done by a common measurement, and in column E are the ones with electric heating. For detached and semi-detached houses the households are classified in four groups: in column B are the heating modes using not electricity or just a little, in column C are the air heat pumps, in column D are the ground-source heat pumps and in column E is the electric heating.

When comparing electricity consumption, location is more relevant factor in households using electricity for heating than in others. In the columns A and B the location does not separate consumption sites. In the columns C, D and E the location separates households in three groups: south, middle and north as explained in Chapter 3.1.4. The locations of households can be classified according to their postal code numbers which will be got from the CRM software.

Classification according to ancillary heating is done in three or two groups. In columns A, B, D and E the classification is done for three sub-groups: firstly wood or nothing, secondly air heat or electric heaters, and thirdly wood and air heat or electric heaters. In column C the sub-groups are non-electrical and electrical. Non-electrical consists of wood or nothing and electrical consists of air heat or other electric or wood and air heat or other electric.

Heated surface area separates the sites in three groups. In column A, the sites consist of only apartments in apartment building and row houses so the separating surface areas should be relatively small. Correspondingly, in columns B, C and D the surface areas should be bigger. Table 3.1 is used for defining the surface areas that will classify the sites. Groups could be formed for example as

- Column A: less than 60 m^2, 60-80 m^2, larger than 80 m^2
- Columns B, C & D: less than 100 m^2, 100-140 m^2, larger than 140 m^2
- Columns E: less than 80 m^2, 80-120 m^2, larger than 120 m^2

Number of residents separates sites in two groups. They depend on a surface size of a site. Table 3.5 is used for defining the number of residents that will classify the sites. The classification according to number of residents is presented in Table 5.3.

Table 5.3. *Classification according to number of residents.*

	Group of the smallest surface area	Group of the midmost surface area	Group of the largest surface area
Column A	1, 2 or more	1-2, 3 or more	1-2, 3 or more
Columns B, C & D	1-2, 3 or more	1-3, 4 or more	1-3, 4 or more
Column E	1-2, 3 or more	1-2, 3 or more	1-3, 4 or more

Construction year separates sites in two groups. As seen in Figure 3.2, the construction year does not have a clear effect on electricity consumption. However, in buildings built after 2005, insulation is relatively better than before that as construction requirements on heat insulation have become tighter. Thus, two groups – built before 2005 and built 2005 or after – are created.

In Table 5.4 the classification of farms and energy houses is defined. Energy houses refers to low, passive, zero and plus energy houses. The number of comparison groups must be small as there are considerably less such of sites in Finland than normal houses.

Table 5.4. *Formation of comparison groups of farms and energy houses. Total amount of groups for farms is 24 and for energy houses it is 32. Energy houses refers to low energy, passive energy, zero energy and plus energy houses.*

	F	**G**	**H**	**I**
Type of a site	Farm	Farm	Farm	Household
Construction quality	Normal	Normal	Normal	Energy houses
Type of an apartment	1	1	1	2
Main heating mode	DH, oil, gas, wood and pellets	Geothermal and air heat pumps	Traditional and accumulating electric heating	2
Location	1	1	1	1
Ancillary	2	2	2	2
Area	2	2	2	2
Residents	2	2	2	2
Year	1	1	1	1
Total	8	8	8	32

In farms the type of an apartment is usually a detached house so it is ignored. Low and passive energy buildings are categorized into two groups by the type of an apartment: apartment buildings and row houses, and detached and semi-detached houses.

Classification according to main heating type is done in three groups for farms depending on the level of electricity consumption of a heating system. Low and passive energy houses are categorized into two groups according to main heating type: heating systems using electricity and systems not using electricity or just a little.

Location is ignored for keeping the number of comparison groups small.

Ancillary heating classifies farms and energy houses in two groups: non-electrical and electrical. Non-electrical consists of wood or nothing and electrical consists of air heat or other electric or wood and air heat or other electric.

Classification according to the heated surface area and number of residents would be smart to define in the future as there will be information on that data. At the moment, it is practically impossible to say which users are from farms or energy houses because such information has not been collected.

Construction year is ignored as there are usually different aged buildings in single farms and so that the number of groups would stay small. In low or passive energy houses the construction year is not crucial.

With the formations presented in this Chapter, the total number of comparison groups in the database would be 398.

The grouping method has not so far classified consumption sites according to their load profile. However, from the AMR-data the different kind of customers, for example retired people and families with children, and customers having various consumption habits could be classified by finding the consumption sites with similar load profiles of typical days. Besides, differences in load profiles due to night-time use would be found out as well. During the study of load profiles of customers who had entered their main heating mode as traditional electric heating, it was found out that in some sites the load profile was equal to customers with accumulating electric heating.

Typical days can be determined in three or seven days in a single month. Three days comprise on weekdays, Saturdays and Sundays, and seven days comprise on each day of a week. Load profile of a typical day of a household is calculated as

$$\hat{E}_{day} = \frac{E_{hour,av}}{\sum E_{hour,av}}, \quad \textbf{(1)}$$

where $\hat{E}_{day}$ is the pattern vector with 24 values representing the load profile
E_{hour} is the hourly average consumption value of a typical day of a month

The load profile for typical days is calculated for every month separately. The clustering technique k-means is used for finding the similar load profiles and it is presented in the following chapter. The k-means is presented more accurately in Chapter 5.3.2.

The example case of load profile clustering consisted of 251 consumption sites. The sites were grouped according to the way presented in column E in Figure 5.2. The sites were normal detached and semi-detached houses with traditional electric heating. They were from Central Finland and the surface areas were 140 m^2 or more, the number of residents was 1-3 and the construction year was before 2005. The data was got from the database which stores the factors that the customers have entered in the current service. The data on ancillary heating could not been used because no such data has not been possible to enter.

The sites were clustered in five groups according to their load profiles from the average consumption of typical days in January 2013 with the k-means technique. In other words, the file that was clustered contained values on the average consumption of typical days per every household for the whole month. The typical days were defined for each day of a week. Then, the number of values for each consumption site for each month was 24*7 = 168. After the clustering was done, the number of sites was 83 in group 1, 41 in group 2, 34 in group 3, 24 in group 4 and 69 in group 5.

Figure 5.5 presents the relative consumption of five clustered groups for each hour per average consumption on Sundays in January 2013.

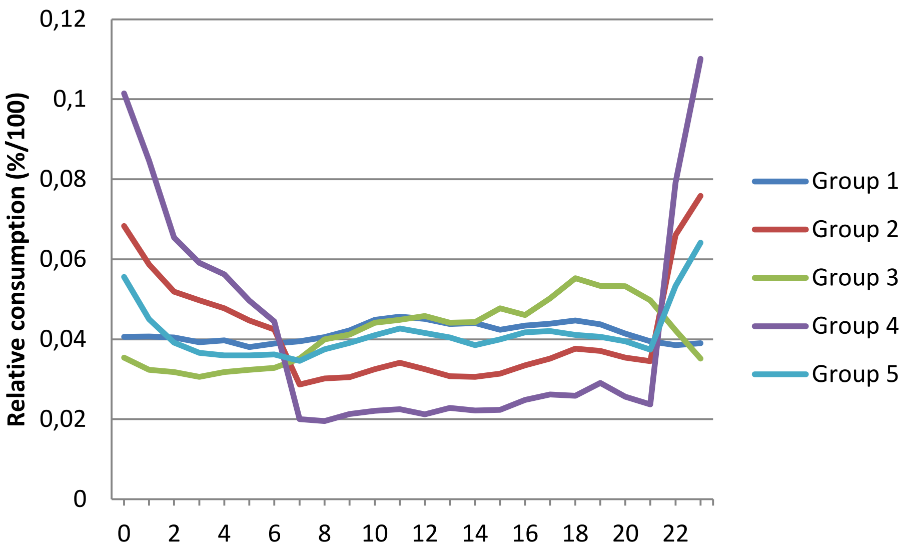

Figure 5.5. *Relative consumption of five clustered groups for each hour per average consumption on Sundays in January 2013.*

The results strengthen the thought that some customers might have entered erroneous data on their main heating mode as the groups 2 and 4 at least seem to be sites with accumulating electric heating. Thus, presented classification in the column E in Table 5.2 for traditional and accumulating electric heating collectively is smart. The AMR-measurements classifies the sites according to different timings on consumption.

Figure 5.6 presents the load profiles on certain days in January 2013 from the consumption sites that were clustered in the group 3 and 4. The blue line presents the average load profile of the groups.

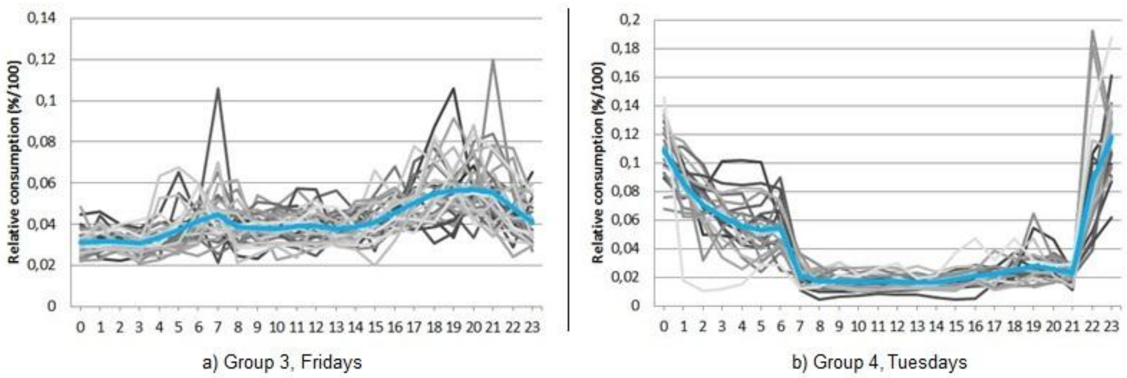

Figure 5.6. *Load profiles of the group 3 on Fridays and the group 4 on Tuesdays in January 2013. The average lines presented as blue.*

There is always variation in load profiles between different consumption sites. However, the number of groups in clustering should not be set too big as some groups might become too small, providing irrelevant comparison data.

The classification according to similar load profiles was also done by defining the typical days for weekdays, Saturdays and Sundays. Figure 5.7 presents the load profiles of the group 3 on weekdays between these two ways to calculate the load profiles of typical days. The lines from Mondays to Fridays result as defining the typical days as each day of a week and the line Weekdays result after defining them as weekdays, Saturdays and Sundays.

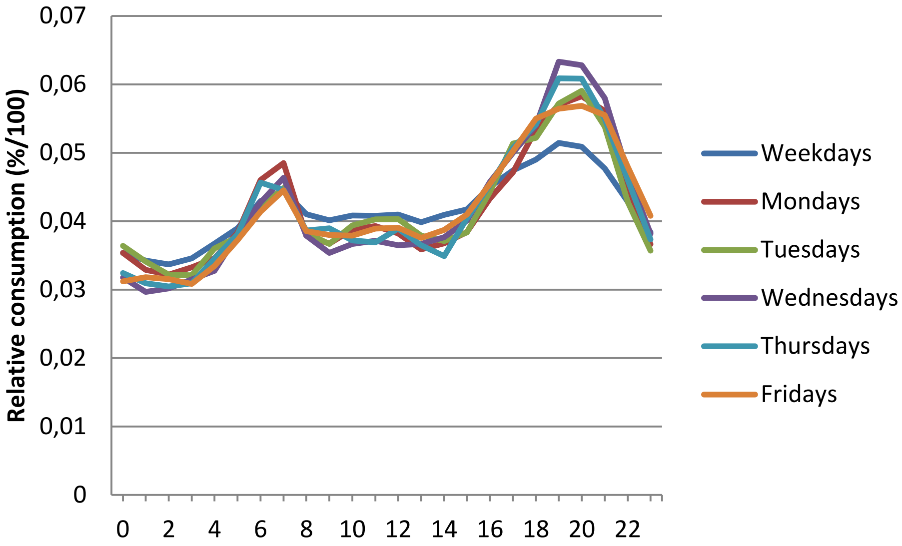

Figure 5.7. *Comparison of relative consumption of the group 3 between the weekdays and each days of weekdays separately.*

The line *Weekdays* is not an average from the other lines as the consumption sites in the groups are not precisely the same due to different definition of load profile calculation. Some consumption sites have been clustered into other groups. However, the results between the ways on load profile calculation are really similar.

Also classification according to the actualized consumption values was executed. However, the last one may not be the good way as it will also classify the sites according to their consumption levels. The point of load profile clustering in this method is to find similarly behaving customers. The other consumption-explaining factors, presented in Table 5.1, will sort out the sites with different factors and consumption levels.

5.3.2 Clustering

In this method, the comparison groups are made based on their consumption profiles and consumption explaining factors. The idea is to first sort consumption sites into pre-groups according to some factors and secondly the final groups are found within the pre-groups by weighted clustering.

Pre-grouping is done for getting the most determining consumption-explaining factors separately. Those are type of a site, construction quality, type of an apartment, main heating mode, ancillary heating and location. The pre-grouping could be done according to the options presented in Tables 5.2 and 5.4. Thus the number of comparison groups after pre-grouping would be 30 for normal households, 8 for households with newer construction technologies and 6 for farms.

Clustering is an analysis technique targeting to get the data to be organized. There are a couple of clustering methods available which can be used. The method called k-means is one of the most popular techniques in statistical data analysis and used in this Thesis as well. The k-means algorithm aims to partition n observations into k clusters in which each observation belongs to the cluster with the nearest mean. The algorithm achieves this by calculating the shortest Euclidean distance between the record’s dimensions and the clusters’ centroid. In other words, the k-means algorithm assigns each point to the cluster whose center, or centroid, is the nearest. The centroid is the average of all the points in the cluster. The number of clusters is k, and it has to be selected manually before clustering. In this thesis, the k-means is used for finding the similar load profiles within the sites that have been pre-grouped.

The clustering of load profiles in this Thesis was done with MATLAB software by using the command *kmeans*. The load profile of a single consumption site is calculated by using the equation 1. The examined group consisted of 251 detached or semi-detached houses from Central Finland with traditional electric heating. In MATLAB the script for clustering is entered as

```
>> real_amr = xlsread(‘amr_data.xlsx’);
>> real_amr(:,1:4) = [];
>> real_amr(1:4,:) = [];
>> amr = real_amr’;
>> january_2013 = amr(1:251,1:168);
>> cluster_jan_13 = kmeans(january_13,5);
>> mean_group_1 = mean(january_13(find(cluster_jan_13(:)== 1),:));
```

The original file *amr_data* contains the load profile data of typical days for the whole year 2013 from the consumption sites that belong to a certain group after the pre-grouping. The file is transmitted into the MATLAB-readable form in the first row. The example file above is in xlsx-form, but also csv-files can be transmitted by the command *csvread*. In the second and the third row all the ancillary data is removed from the columns and rows. The vector that is clustered must not contain anything else than the load profile data. The fourth row turns the vertical vector *real_amr* into the horizontal vector *amr*. The load profile data from a single consumption site must be horizontally because the calculations are done based on matrixes. In the fifth row the load profile data from January 2013 from the vector *amr* is picked to the vector *january_2013*. The kmeans-clustering is then done from *january_2013* for five groups in the sixth row. The seventh row calculates the average load profile for the group 1 from its consumption sites for every hour on January.

Along with load profiles, the weighted clustering takes heated surface area, number of residents and construction year into account when creating the final comparison groups. Each aspect is given a weight according to how much they contribute to electricity consumption in each site.

Linear regression analysis is applied for defining regression coefficients for the properties of heated surface area, number of residents and construction year. The properties are transformed into pattern vectors that describe the consumption sites. Because they have different units and ranges, the data is standardized in prior to clustering. The linear regression analysis is now presented, according to Mononen (Mononen et al. 2014) as

$$E_{\Sigma} = \sum_{i=1}^{n} \alpha_i^B X_i + \beta, \qquad (2)$$

where E_{Σ} is the vector for the total electricity consumption during a typical day for each customer

X_i is the vector for heated surface area, number of residents and construction year for each customer

α_i^B are the regression coefficients for the properties *i*

β is a constant term.

Least-square estimation is used to define the values of α_i^B for *i* = 1, 2, ..., n. According to Mononen, *"the coefficients for the 24 values in the load profile are not defined by the equation 2 as the profile describes the consumption but does not explain it.* However, the similarities between the load profiles in the comparison group must be found and it is required that the weights are assigned to the load data. (Mononen et al. 2014) A balance between the load and the background data is achieved by

$$\alpha^E = \frac{\sum_{i=1}^{n} \alpha_i^B}{24}, \qquad (3)$$

where α^E is the fixed weight for every 24 value in the load profile

The coefficients defined by the equations 2 and 3 are transformed into weights for the refined clustering. This is done by scaling the coefficients to the interval [0,1] so that they sum up to one (Mononen et al. 2014). The weights for the properties *i* are solved as

$$\omega_i = \frac{\alpha_i}{\sum \alpha^B + 24\alpha^E} \qquad (4)$$

where ω_i is the weight for the property *i*, for *i* = 1, 2, …, n
α_i is the regression coefficient in respect to *i*

Then, the weights of the properties are utilized in the k-means clustering algorithm that is applied in order to cluster the pattern vectors into similar groups. The weights are taken into account by modifying the Euclidean distance that k-means is based on. The distance of households *x* and *y* is defined as (Mononen et al. 2014)

$$d(x,y) = \sqrt{\sum_{i=1}^{n} \left(\omega_i(x_i - y_i)\right)^2} \tag{5}$$

The final clustering could then be performed with the k-means algorithm. The number of k should be applied relatively small compared to the number of households after pre-grouping to avoid getting too few households in the final groups.

The method clustering was not tested in practical in this thesis. However, the k-means algorithm was used in method grouping for finding the similar load profiles between households after the grouping according to their consumption-explaining factors.

5.4 Temperature correction

It is very well-known that outdoor temperature has an effect on electricity demand. Decreased temperature raises electricity demand as more power is needed for heating. Outdoor temperature is the most important weather factor but also wind, solar radiation, humidity and air pressure have an effect on electricity demand (Siirto 1989; Seppälä 1996; Meldorf et al. 2007). However, calculations would become very complex if others than outdoor temperature were taken into account. Besides, other factors would not provide a large improvement on results. (Mutanen 2010)

Temperature correction is used widely in Finland in network calculations, load forecasting and tariff planning for example. In Finland, a lot of different heating options are available and this, combined with large and quick temperature variations, results the modeling of the temperature dependency important in the statistical analysis of customer loads. (Mutanen et al. 2011)

The modeling of temperature correction could be used also for offering comparison feedback for customers. However, a lot of measurement points on temperature would be needed from a large area for being able to use temperature correction in normative comparison. Temperature correction is more accurate the more measurement points of outdoor temperature are available.

In this Thesis the temperature correction is done for being able to present a customer the consumptions from different years in a same temperature. The outdoor temperature dependent part of the load is modeled, according to Mutanen (Mutanen 2010), as

$$\Delta P(t) = P(t) - P_{ref} = \alpha * (T_{ave} - T_{ref}) * P_{ref} , \quad (6)$$

where $\Delta P(t)$ is the outdoor temperature dependent part of the load P at time t
$P(t)$ is the actualized consumption of a site at time t
P_{ref} is the load in the reference temperature
α is the temperature dependency parameter [%/°C]
T_{ave} is the average outdoor temperature at time t
T_{ref} is the reference temperature of a month (temperature to which the consumption is wanted to be corrected)

The model provides sufficient results if the temperature dependency parameter α is chosen correctly. A common assumption has been that a 1 °C change in outdoor temperature causes a 4 % change in electric heating load. This rule is applied to consumers with electric heating as their main heating mode. It is assumed that no other consumers have any temperature dependency. However, practically all consumers have certain temperature dependency and the dependency varies between different months. (Mutanen 2010)

Thus, seasonal or monthly temperature parameters could be calculated. Mutanen states that seasonal parameters follow monthly parameters reasonably well and that seasonal parameters can be determined more statistically reliably as the parameters are based on one-year measurements and because there are more days consisted in the calculations (Mutanen 2010). On the other hand, that suits better on traditional temperature correction and modeling of load profiles: The dependencies can vary a lot between consecutive months and same months between different years. The purpose is to present a consumer the consumption between different years where the effect of outdoor temperature is neutralized. So, in this thesis the monthly dependencies are calculated.

The temperature dependency parameters can be calculated from the AMR data. Thus, the parameters would differ between several months and be based on real measurements on consumption and temperature. Same temperature dependency parameter is used for all hours in each month.

Consumption usually does not follow the changes of outdoor temperature immediately as the heat is stored in buildings. Besides, different consumers have different time delays in temperature dependency. Mutanen has stated that a 24-hour delay provides suitable results for all customer classes. If temperature correction is done with previous day’s average temperature, as a one-day delay, the first hours of the day can reliably be corrected but the last hours of the day do not. If previous 24-hour measurements are difficult to be got, Mutanen has also stated that the ongoing day’s average temperatures correlate mainly better with the daily energies than the ones from previous day. (Mutanen 2010) However, the differences were not very large. The average temperature between the ongoing and the previous day is used in this Thesis as temperature data may not be got from every hour.

Adaption in the service

The temperature dependency parameters are calculated by using linear regression analysis for every month separately. Linear regression analysis clarifies when it is statistically correct to use the temperature correction. The analysis finds whether there has been clear dependency between consumption and outdoor temperature. (Mutanen 2010) Sometimes the clear dependencies are not found, due to occasional reasons on consumption for example.

For being able to sort out occasional reasons on consumption, the consumption of typical days for each month is used. Typical days of a month are either comprised on weekdays, Saturdays and Sundays, or on each day of a week.

Sometimes the daily consumption is so scattered that reliable values for temperature dependency parameters cannot be determined. The correlation coefficient r and the Student's t-test can assess the significance of relationship between the daily consumption and outdoor temperature. If the correlation is not significant, or in the other words there seems to be no proper relation between daily consumption and outdoor temperatures, the target site should not be temperature corrected because the real correlation could be zero or even opposite in sign. The correlation is significant if the calculated value of t is larger than the reference value of t from t-distribution table with a chosen probability level. The reference value t is picked from one-tail t-distribution table with N-2 degrees of freedom. (Mutanen 2010)

$$t = r\frac{\sqrt{N-2}}{\sqrt{1-\ r^2}}, \tag{7}$$

where N is the sample size (number of days on calculation)

r is the correlation coefficient

The correlation coefficient r refers to significance of a relationship between two variables. As the reference value t is picked from one-tail distribution table, the reference value for r is solved as

$$r = \frac{t}{\sqrt{(N-2)+\ t^2}} \tag{8}$$

Thus, the significance of correlation can also be presented as if the calculated value of r is larger than the reference value of r, the temperature correction should be done. Part of one-tail t-distribution table and the corresponding values for r are presented in Table 5.5. The values for r are calculated according to the Equation 8.

Table 5.5. *One-tail t-distribution table with a probability level of p = 0,05. The reference values for r are calculated according to the Equation 8.*

Number of days in a month (N)	N – 2	t	reference value r
31	29	1,699	± 0,300877
30	28	1,701	± 0,306035
29	27	1,703	± 0,311442
28	26	1,706	± 0,317287

The real correlation coefficient r is then solved from the AMR-data and outdoor temperature as

$$Correl(E,T) = r = \frac{\sum(E-\bar{E})(T-\bar{T})}{\sqrt{\sum(E-\bar{E})^2\sum(T-\bar{T})^2}}, \tag{9}$$

where $(E-\bar{E})$ is the relative difference of consumption in % between a day and the corresponding typical day

$(T-\bar{T})$ is the difference of outdoor temperature in degrees between the average temperature from two consecutive days and the corresponding typical day

Solution of Equation 9 is the real correlation coefficient r. The significance between the correlation of temperature and load can now be solved by examining the reference r and the real r. If absolute value of the real correlation coefficient is bigger than the absolute value of the reference value, the temperature correction should be done. Then we have to calculate the temperature coefficient α. It is solved as a slope from the (E,T) – curve and is presented as

$$\alpha = \frac{\sum(E-\bar{E})(T-\bar{T})}{\sum(E-\bar{E})^2} \tag{10}$$

The Equation 6 is then transformed into the following form for solving the temperature corrected consumption in the reference temperature. The temperature corrected load is solved as

$$P_{ref} = \frac{P(t)}{1+\ \alpha * \left(T_{ave}-T_{ref}\right)} \tag{11}$$

Figure 5.6 presents the reference temperatures T_{ref} from different part of Elenia's network. The values are calculated as averages from Table 3.4. South is comprised by

Kanta-Häme, Päijät-Häme and Pirkanmaa, middle is comprised by Southern Ostrobothnia and Central Finland, and north is comprised by Northern Ostrobothnia.

Table 5.6. *Comparison temperatures T_{ref} from different parts of Elenia's network domain.*

	South (°C)	Middle (°C)	North (°C)
January	-6,1	-7,9	-9,6
February	-6,7	-8,2	-9,3
March	-2,6	-3,6	-4,8
April	3,4	2,5	1,4
May	9,9	8,9	7,8
June	14,2	13,7	13,5
July	16,9	16,4	16,5
August	15,0	14,1	14,1
September	9,8	8,9	8,9
October	4,7	3,8	3,3
November	-0,5	-1,8	-2,8
December	-4,3	-5,9	-7,1

The example case of temperature correction is presented next. The example household used is a 55 m^2 semi-detached house with a traditional electric heating. The temperature measurements are done 42 km away from the site. The measurements and the results from the temperature correction in the example case from selected days are collected in Table 5.7.

Table 5.7. *The results from the example case of temperature correction.*

Date	Original consumption [kWh]	Average temperature [°C]	Reference temperature [°C]	Reference r	Actual r	Temperature dependency parameter	Temperature corrected consumption [kWh]
31.1.2012	35,05	-21,32	-8,7	0,30	-0,93	-0,04216	22,60
31.1.2013	22,16	-0,52	-8,7	0,30	-0,54	-0,00100	24,36
30.4.2012	12,25	5,98	1,3	0,31	-0,58	-0,04865	15,72
30.4.2013	23,17	5,26	1,3	0,31	-0,47	-0,03149	26,12
31.7.2012	2,39	19,96	16,8	0,30	0,24	0	2,39
31.7.2013	8,1	18,05	16,8	0,30	-0,19	0	8,1
31.10.2012	14,12	-0,71	3,8	0,30	-0,78	-0,08239	9,81
31.10.2013	28,34	2,75	3,8	0,30	-0,15	0	28,34

It is seen that when average temperature has been lower than the reference temperature, the temperature corrected consumption becomes smaller than the original one. Vice versa, when the average temperature has been bigger than the reference temperature, the temperature corrected consumption becomes bigger than the original one. As examined for consumptions of January, it is seen that consumption in 2012 was bigger than in 2013, but the temperatures were also remarkably smaller. The temperature corrected consumptions instead are really similar, actually even bigger in 2013.

In July 2012, July 2013 and October 2013 the consumption is not corrected as there have not been clear statistical dependencies between temperatures and consumptions. The absolute value of actual r has been smaller than the absolute value of reference r, which results that no temperature correction has been executed. The customer has to be informed the reason for no temperature correction done.

The figure 5.8 presents the actualized and temperature corrected consumption from an example site in January 2012 and 2013. The actualized consumption was 680 kWh in January 2012 and 842 kWh in 2013. The temperature corrected consumption was 662 kWh in 2012 and 854 kWh in 2013.

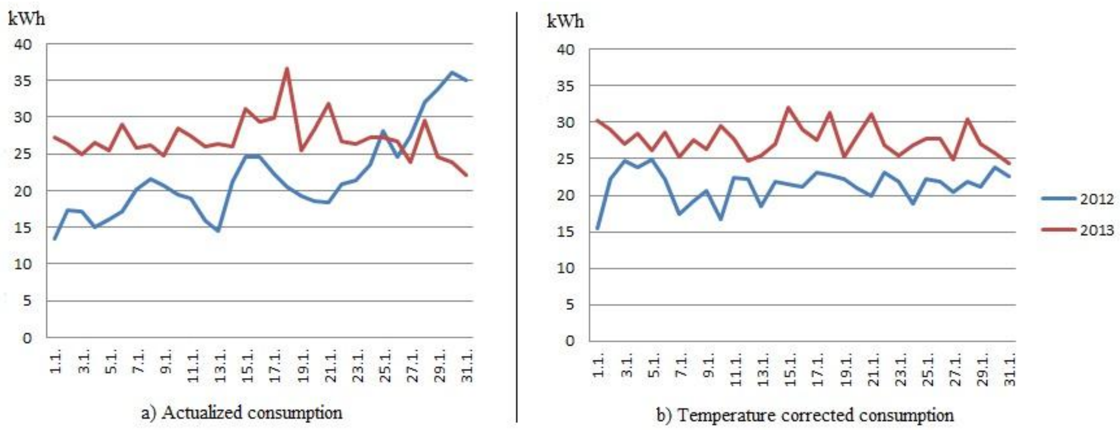

Figure 5.8. *Actualized and temperature corrected consumption from an example site in January 2012 and 2013.*

As a result, the consumption curves have become flattened. As the January was colder month in 2012 than in 2013, a customer has consumed remarkably more electricity in 2013. The average temperature was -9,46 °C in January 2012 and -7,21 °C in January 2013.

6 FUTURE SERVICE DEVELOPMENT

The habits on using electricity have changed. During the last decade the use of entertainment electronics has increased, various heat pumps and air conditioners have become more common and lighting efficiency has increased for example. Thus, they have caused clear change to the old customer class load profiles. (Mutanen 2013)

In future, the change of consumption habits of private consumers will probably keep on. Housing automation is becoming more common, systems will be refined and new appliances will be developed. Also operation of electricity markets target into more efficient use of electricity and flattening the consumption peaks. Households are probably encouraged into more automated systems and cutting peak loads. Adapting demand according to supply will become more and more important as more renewable energy and distributed generation will be applied in the future.

The utilization of DR, electric vehicles and DG for example will become more common in the future. Online consumption reporting services could be used in future for notifying consumers on the levels of consumption that has been consumed by smart grid appliances. As the smart grid technologies are applied, also systems controlling and measuring the consumption of them could be applied. The consumption of them might be connected to a database of a DNO and further, to a reporting service. In case of DG, it was held as the most customer-activating scenario on customers' benefits towards smart grids by the research group in the release of Heiskanen et al. Power generation would also raise interest on monitoring, dynamic load control and generally controlling on energy consumption. In case of electric vehicles, consumers are a bit skeptic towards electricity supplied into the grid from the batteries of electric vehicles (Heiskanen et al. 2012).

More diverse reporting service

According to the release on customers' benefits towards smart grids (Heiskanen et al. 2012) and development of the housing automation, even more diverse reporting services are needed in the future. Well refined, personalized and accurate saving-tips-including reporting service was the most interesting smart-grid service among the research group in the research of Heiskanen et al.

The research group suggested tailored reporting services for consumers because of variable interests, appliances, work periods and habits to spend their free-time. The more factors that are known from a consumption site the more accurate comparison data or analyze on consumption would be offered. The clustering methods will already target on finding similar load profiles and consumers with different behavior. More detailed and automated analyze of consumption would basically need the utilization of HEMS for being separate consumptions due to different appliances. For example, classifying consumption in at least heating and appliances, and appliance group to even more subgroups, would probably achieve large knowledge on specific consumption in a single site. HEMS provides a consumer knowledge with monitoring systems, which may be linked to reporting services to tell data on consumption changes compared to past. Visualized data would increase the knowledge among the whole family members. Without HEMS the appliance-specific consumption breakdown is practically impossible to achieve.

Increasing the target group for comparison data

In addition to households, also farms, households with modern construction techniques, real-estate properties and similar business apartments could be offered comparison data. The suggestion on offering comparison data for farms and households with modern construction techniques was presented in Chapter 5.3.1.

The classifying data for real-estate properties should contain at least the surface area of the real estate property, data on the energy class or construction techniques, main heating mode, number of apartments and number of static car heaters. The consumption data could be provided from the whole real-estate property or from the common areas where the consumption of apartments' heating and warm water is ignored.

Business apartments would be needed the information on the type of the business and several consumption-explaining factors presented in this thesis. The comparison between business apartments is more difficult though than in other private customer groups. Thus, the business apartments could be provided other kind of feedback on their consumption.

Demand response

The methods of DR are hourly-based tariffs and dynamic load control. The main purpose of DR is to cut peak loads in the network. There is need for DR as it decreases CO_2 emissions and the need for reserve power. The popularity of DR will probably increase as more renewable energy is applied because the generation will vary between hours, days and seasons. At the moment, demand response has been studied and modeled quite a lot but it has not broken through among private customers. According to Heiskanen et al. (Heiskanen et al. 2012) the research group stated the dynamic load control would be the more acceptable method on DR. However, the research group stated that appliances adapting consumption according to the price of electricity is an interesting and worthwhile trend of development.

Customers' interests towards DR depend highly on benefits available, effort required and how DR is packaged for customers like what products, services and automation are included and how the idea is presented. Thus, there have to be clear, basically monetary, benefits and DR has to be easy and require neither a lot of effort nor major investments. Idea has to be presented in simple and easy-to-understand way. (University of Vaasa & ABB 2013)

The research group in the release of Heiskanen et al. suggested that consumers with electric heating could be involved dynamic load control against a little repayment and consumers in apartment buildings could get couple of controlling devices connected to power sockets free.

Most appropriate devices for DR are accumulating electric heating equipment, boiler, under floor heating, automated ventilation and heat pumps as they do not require activity from consumers on a daily basis. (University of Vaasa & ABB 2013)

If DR becomes more common for private customers, customers could be offered a possibility to monitor their load control or see the hourly electricity prices in the reporting service. The customers would like to see the times of dynamic load control and which appliances have been controlled. It would need the appliance measuring only consumption of appliances. As consumers would like to have different appliances to be controlled in the future the HEMS solutions might be the best way on monitoring consumption of DR.

Abnormalities and changes in consumption

The changes in consumption levels or load profiles may refer to the changes in consumption-explaining factors or change in consumption behavior. Thus, they could be applied in the future to get more interactivity to the service. The service would automatically inform customer on notifying changes in consumption behavior for example. If significant changes in load profiles or consumption levels are noticed, a customer would be informed for updating the data on his or her consumption site. At the moment, there is research going on about the issue in TUT.

The analysis on noticing abnormalities in consumption could be offered as it has been studied more. Customers have a lot of diversity in their consumption and some unusual levels on consumption may result on consumption of certain appliance. Though, informing on abnormalities may be really challenging.

7 CONCLUSION

In this thesis, guidelines and possibilities for developing especially the comparison feedback in the electricity consumption reporting service for private customers were carried out. As the development of comparison feedback is related to consumption feedback, tools and attributes aiming to better feedback in general are presented as well. The service is offered by electricity distribution company Elenia Oy for its private customers. Besides, one aim was to compose more interactivity in the service. The purpose of developed electricity consumption reporting service is improving customer service, decreasing number of customer contacts, fulfilling the regulation on energy efficiency and informing about customer-orientation. Proper consumption reporting is one of the best chances for decreasing electricity consumption of private customers and further, carbon dioxide emissions and proper operation of the grid. Besides, the service is one of the best ways to utilize vast AMR-data.

Companies operating in energy sector are involved in more efficient use of energy and actions for achieving their customers decreasing consumption as well. Studies have shown that proper feedback on consumption stimulates electricity savings and reduces the costs. Savings have been found from 1,1 % to over 20 % per household.

Feedback that is most effective successfully captures the consumer's attention, draws a close link between certain actions and their effects and activates various motives that may appeal to different consumer groups, such as monetary savings, resource conservation, reduction of emissions, competition to similar consumers and others. Thus, simple but diverse tools of feedback should be provided; simple that they would be understood and diverse that the appealing motives would be clear.

In most researches, the monetary savings are said to be the most motivating factor for reducing the consumption. Besides, consumers are all the time more and more interested on environmental issues. Thus, offering information on costs, possible savings and CO_2-emissions due to consumption are important ways to motivate consumers for more effective use of electricity.

The current comparison feedback in the reporting service is not relevant enough. As the classification does not take factors enough into account, the comparison data can be inaccurate. Besides, in future the change in consumption behavior will keep on due to new smart grid technologies. Thus, the service needs to be improved as customers could be offered more accurate possibilities to monitor their consumption.

Attributes on comparison to household's historical consumption, consumers with similar factors and load profiles and selected types of consumers were mainly examined in this thesis. For being able to offer comparison data, the comparison groups must be defined. Two different methods were presented in this Thesis: grouping and weighted clustering. However, the weighted clustering was not tested in this Thesis in practical.

The purpose in grouping is to classify the consumption sites in several groups with similar consumption-explaining factors. The consumption habits and timings on consumption are found by the load profiles with the k-means clustering method.

The weighted clustering relies more on statistical and calculative methods than grouping. The purpose of this method is to pre-group the consumption sites according to most consumption-effecting factors and then with statistical tools, calculate the final comparison groups according to the less consumption-effecting factors and load profiles.

The results from the development on formation of comparison groups can be find out after they are updated in the service.

Interactivity of the service can be improved by goal setting and alarms. The goal setting will give a customer a chance to set monthly targets on consumption. The alarms will inform the customer on consumption exceeding the monthly target, consumption about to exceed the monthly target and consumption being too low during a selected time period. Thus, customers may be motivated to use the service, to reduce their consumption or to be notified on abnormal consumption.

Modeling of temperature correction for being able to offer customers reliable comparison data on their electricity consumption from previous years was also examined in this Thesis.

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APPENDIX 1: GENERATION OF SOLAR POWER

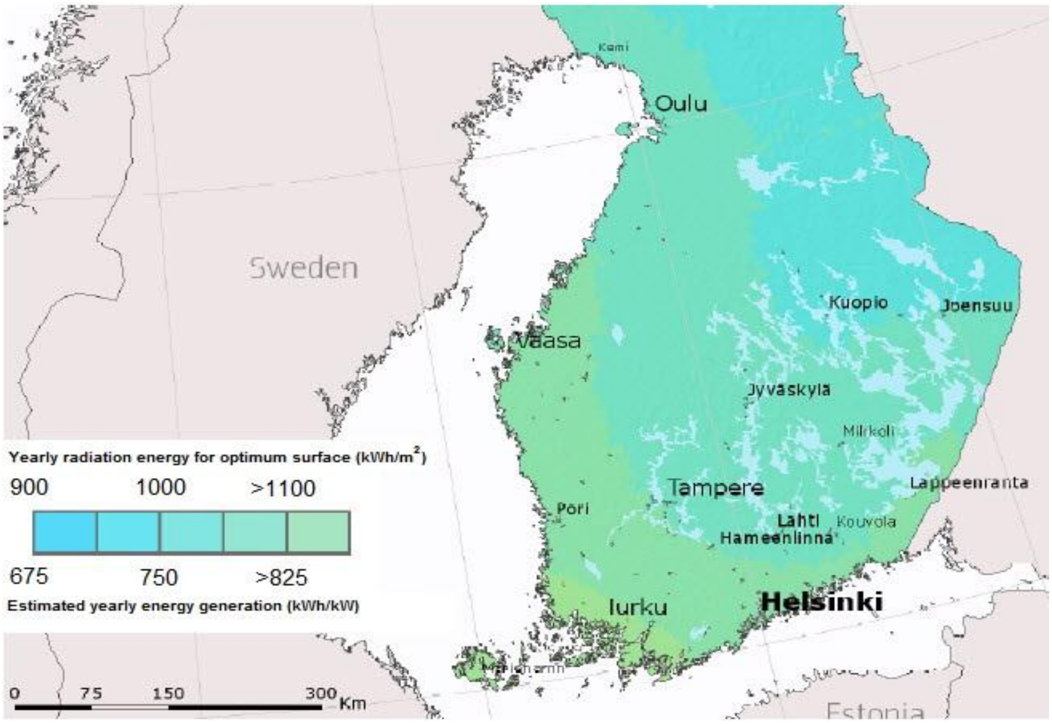


Figure. *Yearly radiation energy for optimum surface and estimated yearly energy generation with a solar power unit with a nominal power of 1 kW. (Modified from Paavola 2013)*

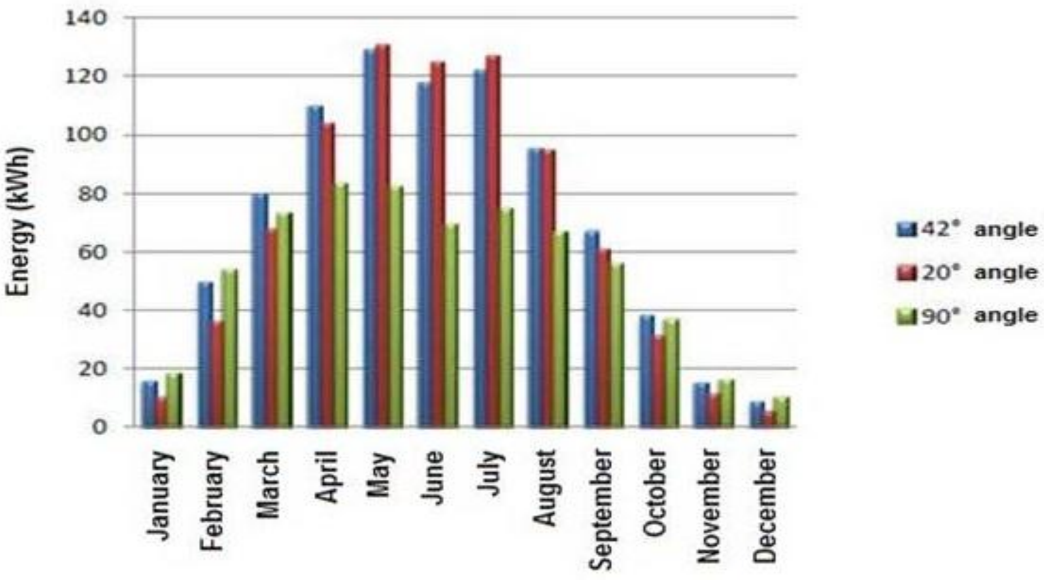
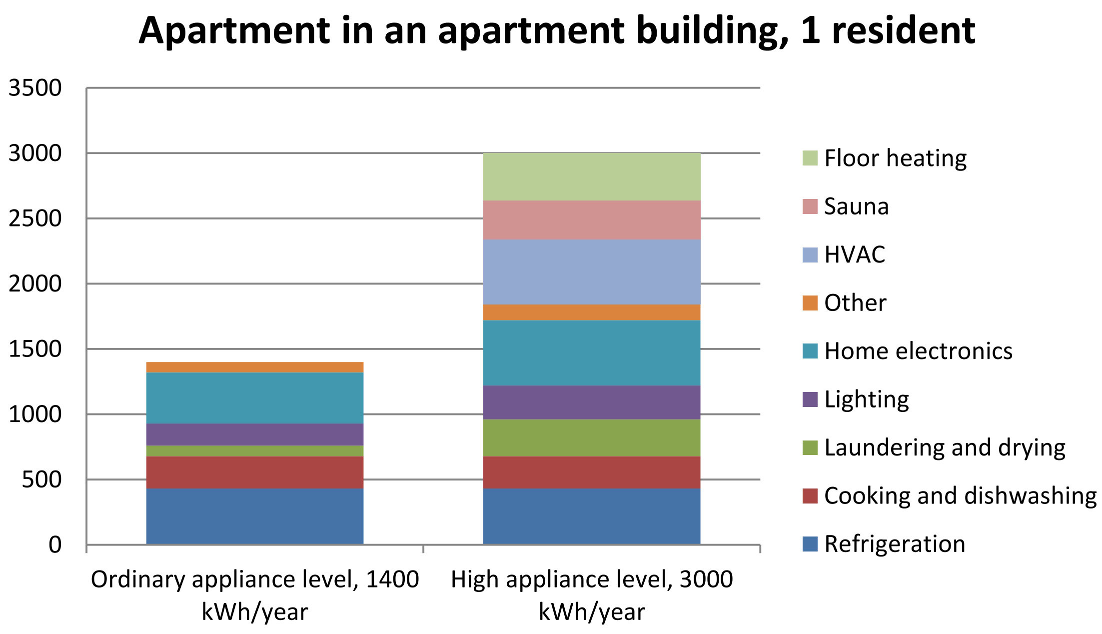
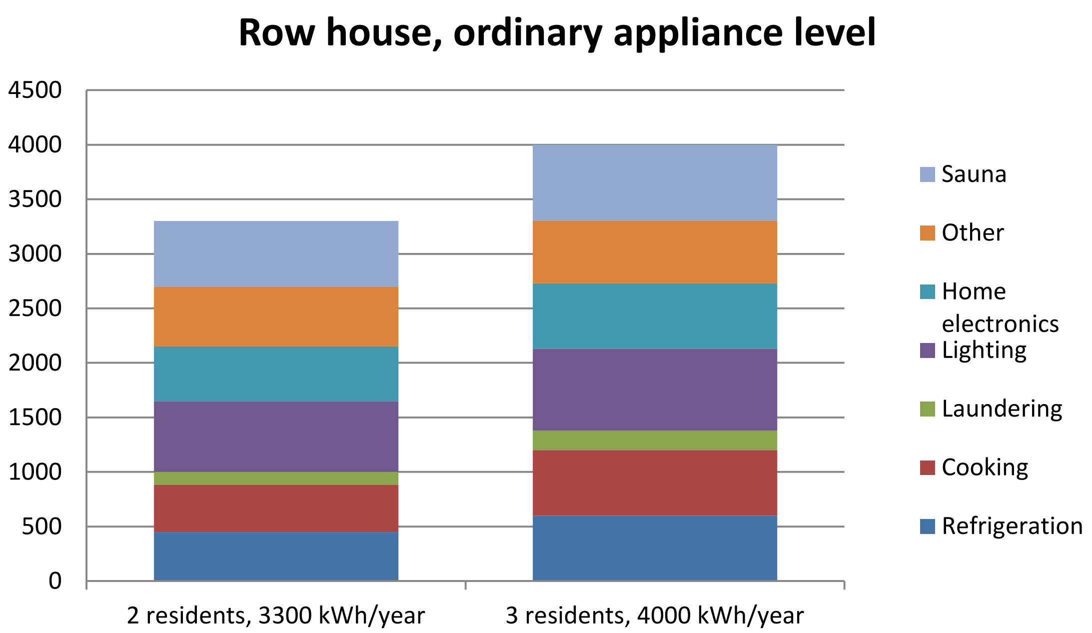
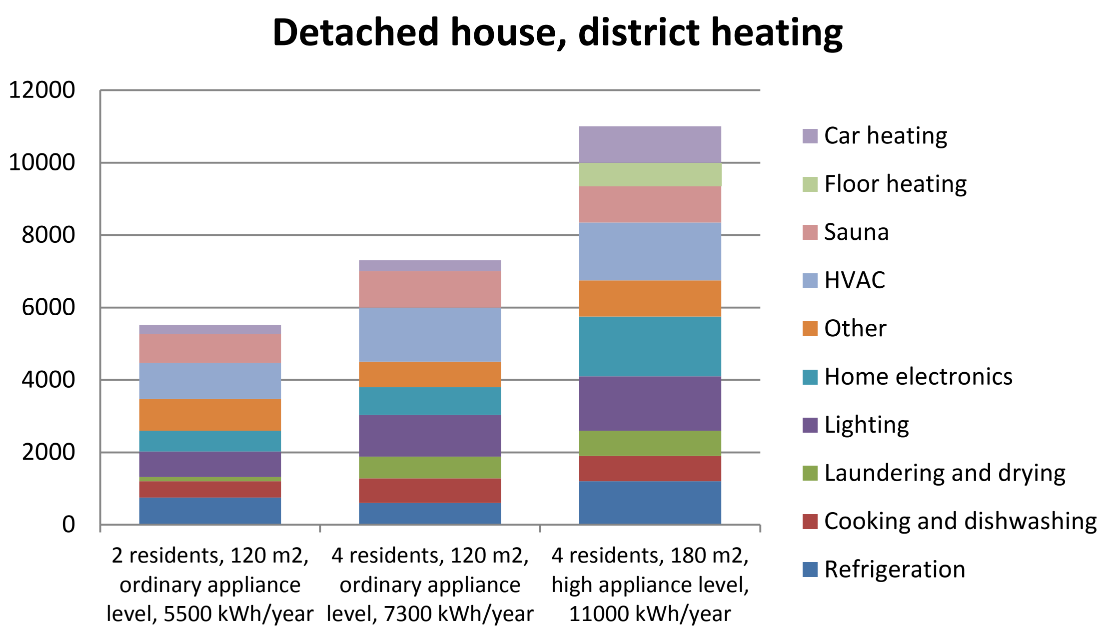


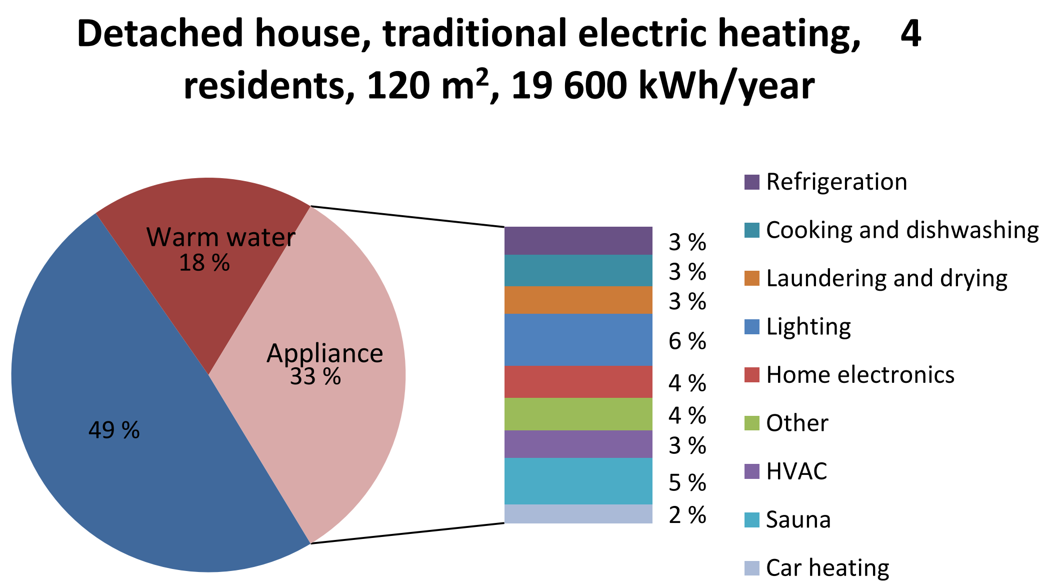
Figure. *Estimated generation of a solar system with a nominal power of 1 kWh in Tampere with different angles of solar panels.*

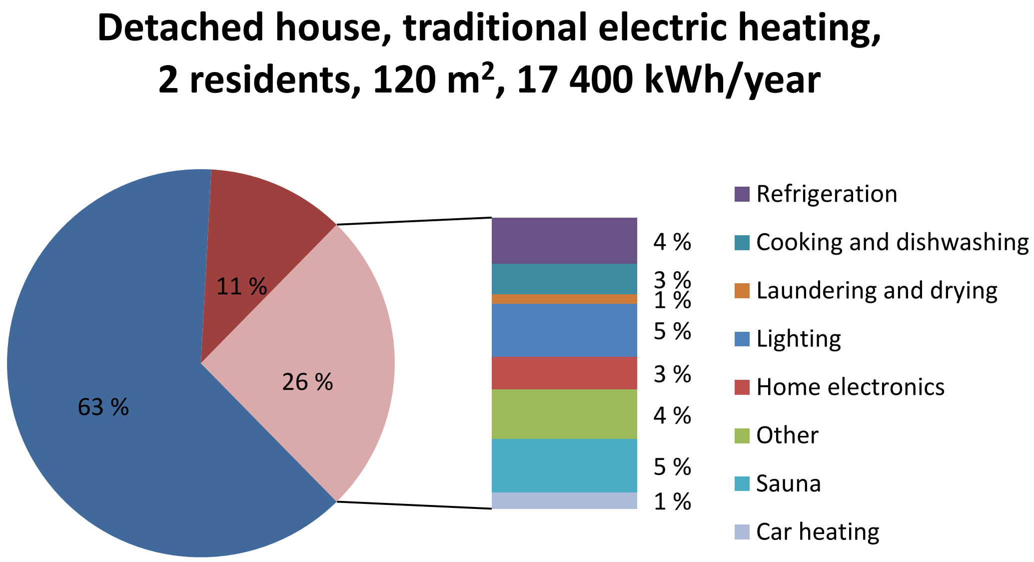
APPENDIX 2: CONSUMPTION OF EXAMPLE HOUSEHOLDS






Detached house, district heating
12000
10000
8000
6000
4000
2000
0
2 residents, 120 m2, ordinary appliance level, 5500 kWh/year
4 residents, 120 m2, ordinary appliance level, 7300 kWh/year
4 residents, 180 m2, high appliance level, 11000 kWh/year
Car heating
Floor heating
Sauna
HVAC
Other
Home electronics
Lighting
Laundering and drying
Cooking and dishwashing
Refrigeration


Detached house, traditional electric heating, 4 residents, 120 m², 19 600 kWh/year
Warm water
18 %
Appliance
33 %
49 %
3 %
3 %
3 %
6 %
4 %
4 %
3 %
5 %
2 %
Refrigeration
Cooking and dishwashing
Laundering and drying
Lighting
Home electronics
Other
HVAC
Sauna
Car heating


Detached house, traditional electric heating,
2 residents, 120 m², 17 400 kWh/year
11 %
26 %
63 %
4 %
3 %
1 %
5 %
3 %
4 %
5 %
1 %
Refrigeration
Cooking and dishwashing
Laundering and drying
Lighting
Home electronics
Other
Sauna
Car heating