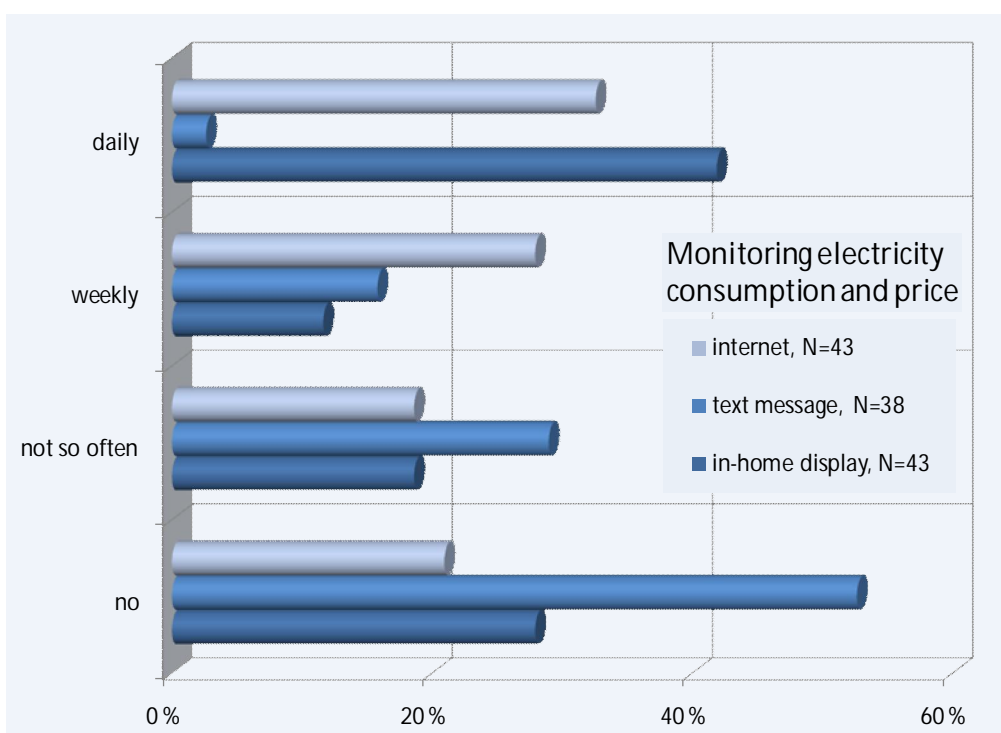


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## Consumer acceptability and adoption of Smart Grid



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**SGEM Research Report D1.2**

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## **Consumer acceptability and adoption of Smart Grid**



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Smart Grids and Energy Markets

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Report Title:

## **Consumer acceptability and adoption of Smart Grid**

SGEM Theme 1 - Smart Grids architectures

WP1.2 Customer behaviour and society development

Key words: Smart Grid, customer behaviour, consumer acceptance, consumer view, regional modelling

### **Abstract**

The report presents the preliminary phase of studies carried out in SGEM work package 1.2 concerning customer behaviour in the context of Smart Grid technology. The focus of the studies is on household consumers in Finland and Sweden. The common goal of the task is to produce knowledge that can be used to facilitate and enhance the consumers' adoption of the Smart Grid system.

One part of the work focuses on consumer acceptability, in order to gain a preliminary conception of factors that are relevant from the consumers' point of view. The acceptability of Smart Grid is studied by using different perspectives. The consumers' opinions and expectations of their use of energy and of Smart Grid technology is explored on the basis of investigations of customer service interactions at an energy company in Finland and Sweden and inquiries carried out in Finland. Communication on Smart Grid to the consumers is studied by considering Smart Grid technology as a new innovation and the quality of the provision of information to the consumers within the Smart Grid context. In addition, the society view on the consumers' adoption of Smart Grid technology is shortly discussed.

The other part of the work focuses on refining a basis for computational method to predict regionally the consumers' adoption of smart grid related innovations and the consequent effects on the electricity loads. Since innovations such as electric vehicles and micro generation are integral part of the smart grid vision, modelling their regional adoption can also help to reflect the usefulness and potential of the smart grid technology as a whole.

Espoo, March 2011

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## **Preface**

The work presented in this report is part of the project SGEM, Smart Grids and Energy Markets. The SGEM project belongs to Cluster of Energy and Environment (CLEEN), financed by Finnish Funding Agency for Technology and Innovation, TEKES industrial partners, universities, and research institutes.

We wish to thank the funding organizations and the steering group of SGEM programme for making this work possible to carry out.

The authors

## Abbreviations

AMI	Advanced Metering Infrastructure
AMM	Automatic Meter Management
BRP	Balancing Responsible Parties
CEN	European Committee for Standardization
CENELEC	European Committee for Electro technical Standardization
CIS	Customer interaction and service
CPP	Critical peak pricing
DER	Distributed Energy Resources
DG	Distributed generation
DSO	Distribution system operator
DWH	Domestic Water Heater
ETSI	European Telecommunications Standards Institute
EV	Electric vehicle
GIS	Geographic information systems
HAN	Home Area Networks
LAN	Local area network
MLR	Multiple linear regression
PTR	Peak Time Rebate
RES	Renewable Energy Sources
RTP	real-time pricing
SG	Smart Grid
SGEM	Smart Grid and Energy Market
SOM	Self-organizing map
ToU	Time-of-Use tariff
TSO	Transmission system operator
UEF	University of Eastern Finland - Itä-Suomen yliopisto



# 1 Introduction

Knowledge of customer behaviour helps in finding out aspects that would increase the acceptability of Smart Grid technology and support the adoption of the system. One essential aim of future energy market and Smart Grids is that customers are active, which means that they buy, sell, and control their electricity use and/or permit it to be controlled. Distributed intelligence and local optimisation presume that all power system participants will have local intelligence which will be used to optimise their real time response to the changes in the power system.

This report presents the work carried out in the SGEM work package 1.2. The common goal of the three tasks of the workpackage was to produce knowledge that can be used to facilitate and enhance the adoption of Smart Grid technology. The focus of the studies was on household consumers. The choice was motivated by the fact that customers like small industry, business or office premises, schools or other medium size consumers already react on energy saving or load shifting on a more professional basis than a normal household consumer. In these cases also the energy consumption exceeds the consumption of households. The studies were concentrated on consumers in Finland and in Sweden.

According to the used approach to the research theme, the work was divided to two parts.

One part of the work, carried out by Fortum and VTT, was focused on consumer acceptability of Smart Grid technology, in order to gain a preliminary conception of factors that are relevant from the consumers' point of view. There is a general agreement on the importance of the consumer view for the success of Smart Grid technology and on the necessity to take this perspective into account in the development of the Smart Grid concept. The emphasis in the design projects has, however, been largely on the technical and economic aspects. In the following tasks of the work package, possibilities to take the consumer view better into account in the development and introduction of Smart Grid technology were considered from different angles, by paying an attention not only to the conceptions and experiences of the consumers but also to the quality of the information provision to the consumers within the Smart Grid context.

Task 1.2.1 Customer activities and interactions. This task was focused on the identification of factors influencing the acceptability of Smart Grid technology from the consumer point of view. The emphasis was on the informational aspects of the Smart Grid concept. Three different perspectives were used here.

The first perspective is describing the Smart Grid as the context of the consumers' usage of electricity. Here, Smart Grid is handled from the technical

and economic point of view, on the basis of the preliminary idea of the concept, adopted in the SGEM project.

The second perspective is exploring the consumers' opinions and expectations of their usage of electricity and Smart Grid technology. The explorations are based, on two types of material. One type concerns investigations of customer service interactions at an energy company, carried out in Finland and Sweden. Analysis of statistics on the customers' incoming phone contacts and interviews of customer service agents was conducted in order to find problems and areas of interest brought out by the customers. The other type of material concerns opinions of consumers, collected with the help of two inquiries carried out in Finland. One of them, a web-inquiry, was made in the SGEM project. The other inquiry, used to complete the material, was conducted in the ASTEKA project [61].

The third perspective is considering communication on Smart Grid to the consumers. Here, first, introducing the Smart Grid solutions to the consumers is reflected in relation to Rogers' model of diffusion of innovations. The model describes how an innovation is spread through different channels and finally is fully accepted and becomes a natural part of end-users lives. Second, the challenges of communicating the Smart Grid concept and technology through the provision of information to the consumers and the implications on possibilities of meeting these challenges in the development of the technology and in the electricity and energy companies are considered. The consideration is based on a contextual approach emphasizing the significance of the consumers' actual possibilities of knowing and understanding the relevant issues concerning the concept of Smart Grid and the use of the system.

Task 1.2.3 Society development. This task discusses shortly the society view on the consumers' adoption of Smart Grid technology. The focus is on the legislation and regulation for promoting the consumers' energy efficiency.

The results of the tasks were used in answering, in this preliminary phase at a general level, the following questions:

1. What kind of concerns, doubts and problems the consumers have brought out concerning their use of electricity and what they expect of Smart Grid technology?
2. What kind of difficulties, i.e. lack of knowledge and understanding, there may be among the consumers, concerning their use of energy with the help of Smart Grid technology and regarding the Smart Grid concept?
3. In which ways could the challenges relating to the provision of information be met in the development of the Smart Grid concept and in the electricity and energy companies, in order to ensure a good quality of information?

The other part of the work carried out in the work package was focused on modelling consumer behaviour for predicting regional electricity consumption. This work was done in the second task of the work package.

Task 1.2.2 Prediction of customer behaviour based on existing database. The work in this task aims at developing a computational method for modelling regional electricity consumer behaviour and the consequent electricity loads.

A model that combines scenario approach to data-driven methods for predicting the regional electricity consumer behaviour and the electricity loads ensued has been investigated in the research group of environmental informatics at the University of Eastern Finland.. Moreover, a web-based pilot application that implements the model has been under development. During the development, answers to the following research questions are being studied:

1. How to predict which customers are most probable to make changes in their behaviour, e.g. change the energy source, obtain an electric vehicle or solar panels?
2. How to construct electricity load curves that can take into account the adoption of new technologies that significantly affect the electricity usage?

A preliminary analysis is made on the research questions to form a basis from which the development of the model can continue on later phases of the SGEM project. This involves investigation on the possible modelling methods and data sources.

The report is organized in the following way. In chapter 2 Smart Grid is described as the context of the consumers' usage of electricity. Chapter 3 presents the investigations and inquiries made for exploring the consumers' opinions and expectations in Finland and Sweden. Chapter 4 presents the considerations on communicating Smart Grid to the consumers. Chapter 5 handles shortly the society view on adoption of Smart Grid. Chapter 6 introduces regional modelling of electricity consumer behaviour and the consequent electricity loads. Finally, discussion and conclusions on the work are presented in chapter 7.

## 2 Smart Grid as the context of consumer's usage of electricity

### 2.1 Preliminary idea of the Smart Grid system

In general, the basic principle of Smart Grid systems is enabling the goals for energy saving and reduction of CO<sub>2</sub> emissions. The measures are regulation, increase of information and economical benefits. Advanced metering is an essential part of Smart Grid concepts which together with dynamic pricing allow the full utilization of the demand response. Distributed generation is now a possibility for individual consumers as well as larger entities.

All the service connections, transformers, transmission infrastructure, substations, generation plants, and everything required to manage the generation and distribution of electrical power is known as the conventional electrical grid [17]. The preliminary idea of the Smart Grid (SG) is to provide technology and systems that will allow consumers to automatically manage their energy use and costs. Figure 1 shows the idea of the Smart Grid.

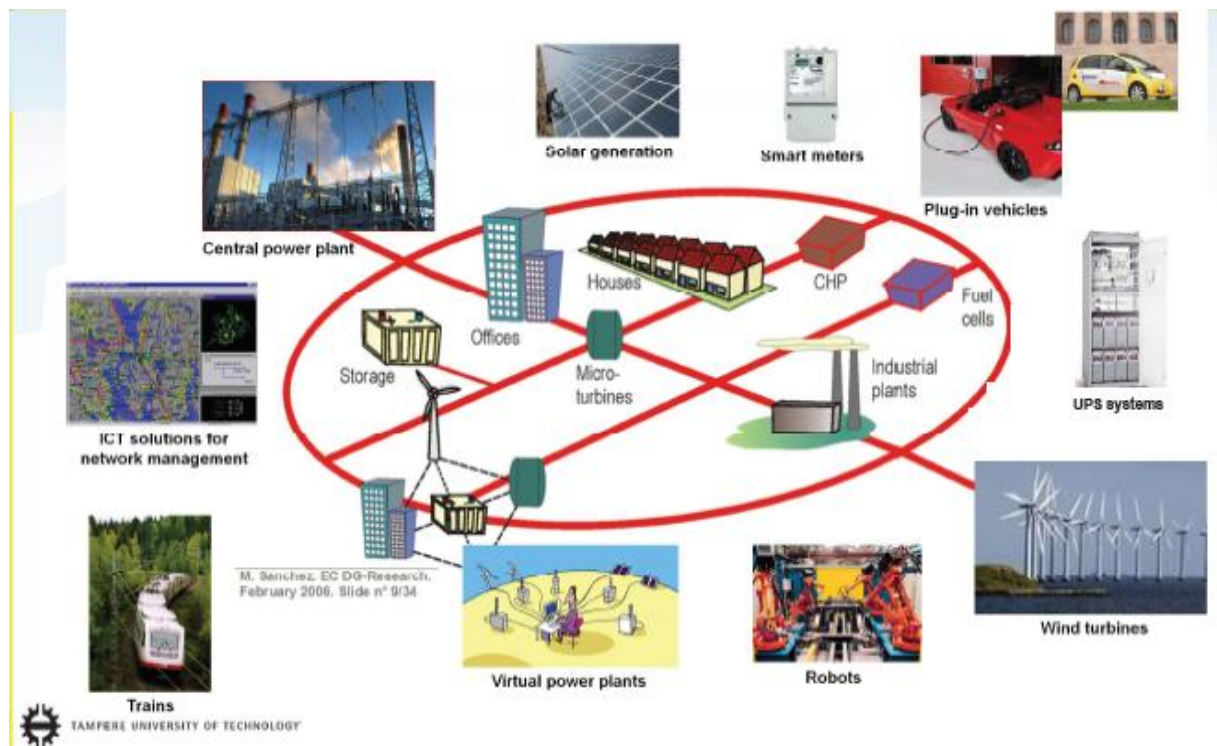


Figure 1 Smart Grid principles [25].

A Smart Grid is an electricity network that can cost efficiently integrate the behaviour and actions of all users connected to it – generators, consumers and those that do both – in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety [35]. The European regulators use and support the approach that investments in smarter networks must result in user value and direct benefits to

all network users, see [Figure 2](#). The addressed challenges and opportunities include:

- User-centric approach
- Electricity networks renewal and innovation
- Security of supply
- Liberalised markets
- Interoperability of European networks
- Distributed Energy Resources (DER) and renewable energy sources
- Central generation
- Environmental issues
- Demand response and load management



*Figure 2 Key elements of a sustainable energy system [35].*

The managing systems can be integrated into appliances and consumers' devices used in everyday activities. The managing system can for instance be controlled by the building automation. In addition, these products can help the grid increase the use of viable alternative energy sources, such as renewable energy. From a consumer perspective, the current grid delivers electricity to their home and it includes everything from the electric meter outside their home back to the power plant. In the future, the Smart Grid is no longer everything from the meter and beyond because the integration of the home and the involvement of the consumer will be integral and necessary components.

A key feature of the Smart Grid is Demand Response (DR), where the consumer, utility or designated third party can reduce the consumer's energy consumption during critical usage periods [17]. The possibilities for the demand response and the control are handled in chapter 2.2. The supply security can be improved in SG system as soon as the technique is ready for islanding operation. The most important issue is maintaining the electric safety in case of several small generation units in the network.

According to the Swedish law relating to electricity (Ellagen 1997:857, Chapter 3) grid owners in Sweden are entitled to connect DG units and allow grid customers to feed electricity back to the grid as long as the production unit fulfils certain requirements on safety and quality of the produced electricity. When combining an electricity storage system together with DG, customers can store energy at situation of excess production to be used at situation of higher power load. This would also help smooth the variable nature of intermittent generation, using these technologies together makes the stochastic situation of DG usage more controllable.

Due to the space required for DG units they have mainly been considered an option for rural areas. Today more compact models, constructed for fitting on rooftops, are being introduced to the market. This would give city customers the possibility of becoming producers. However, not every end-user has got an interest in investing in DG units. With proper regulation the investment could also comprise of just the electricity storage system is charged with electricity bought at situations of low electricity price and there by an access of electricity in the grid. Stored electricity could again be fed back to the grid at a higher price. This could be utilized for levelling out overall differences in demand and generation of electricity. The storage type could be of mobile or fixed type.

End-users can connect just about any type of generation technology available, renewable or non-renewable, as long as it fulfils the requirements set by the grid-owner. Some non-renewable energy generation is a fairly low-cost investment. But implementing too much non-renewable energy resources in the power grid contributes to air pollution instead of lowering it. Most non-renewable energy sources have a controllable nature and would contribute to grid stabilization.

DG, energy storages, EVs, controllable loads are referred to as DER; the end-user has a set of technology which can include generation, storage and control systems. Then the end-user load is no longer passive. DER is an active system that can take energy from the power grid, feed energy to the grid and control loads according to availability of electricity in the grid.

As the number of Distributed Energy Resources (DER) increases, and communication to the various resources becomes more extensive, the ability to operate segments of the grid as islands or Microgrids becomes reality. The drivers are clear - the desire for high availability and high quality power for the digital society. Battery and inverter technology is evolving such that a utility can

justify the capital cost of the installation based on the difference in price from buying energy at night at a low price and selling it back during peak daytime rates [23][30].

## 2.2 Demand response, remote control

In the context of Smart Grids, consumers will receive signals from some electricity actors and will be rewarded, or penalized, for adapting their electricity consumption. This chapter will focus on the technically possible ways that a consumer could use in order to adapt his consumption. We will focus on the different loads that are typically found in a household and see to what extent that can be controlled.

### 2.2.1 Electrical characteristics of the control actions

The first type of loads is **shiftable** loads. Shiftable loads consume the same power, following the same pattern, but can be shifted in time. The second type of loads is **curtailable** loads. Curtailable loads can be switched off or down, and thus reduce their consumption without any need for later recovery.

A perfect shiftable load would displace the time when the power envelope is consumed, but would have no overall impact on the energy consumed. We will discuss further the details of each load, but the situation is in a lot of cases a mixed position between the shiftable and the curtailable load. The load or a part of it is shifted in time, but the total energy consumption is reduced or, sometimes, increased. This happens typically when a load is turned down for a period of time and needs to catch up by consuming more when the control is released in order to bring the situation back to normal. Such a reaction is often referred to as the **pay-back effect**.

### 2.2.2 Domestic electrical loads

#### 2.2.2.1 Electric water heating systems

Water can be heated from different sources and by different means. We are discussing here the heating of water directly from electricity. Water heating can also consume electricity by the use of heat pumps which, for our purposes, can be seen as direct heaters with an improved efficiency.

On-demand heating of water when it is needed is becoming rarer and is relatively seldom in Finland in the case of electric heating. They also do not present much interest from a flexibility point of view. They are hence absent from the following discussion.

Storage water heaters are composed of a boiler and a tank. The heat is produced in the boiler (in our case from electricity) and transferred to the water which is then stored in the hot water tank. Most often, the boiler and the tank are the same unit. The size expressed in litres and the electricity consumption of a water heater depend on the need of hot water. Such a need is usually

determined by factors such as the number of users, or the size of the household, and the uses that water will have (shower or bath, need for space heating...).

Table 1 shows the typical power of a Domestic Water Heater (DWH) according to its tank's size while Figure 3 shows the typical consumption of a storage water heating system.

Table 1 Typical electrical power consumption of electrical boilers depending on the tank size

Capacity of the DHW storage tank	50-100 l	150 l	200 l	300 l
Electrical power	1.2 kW	1.8 kW	2.2 kW	3 kW

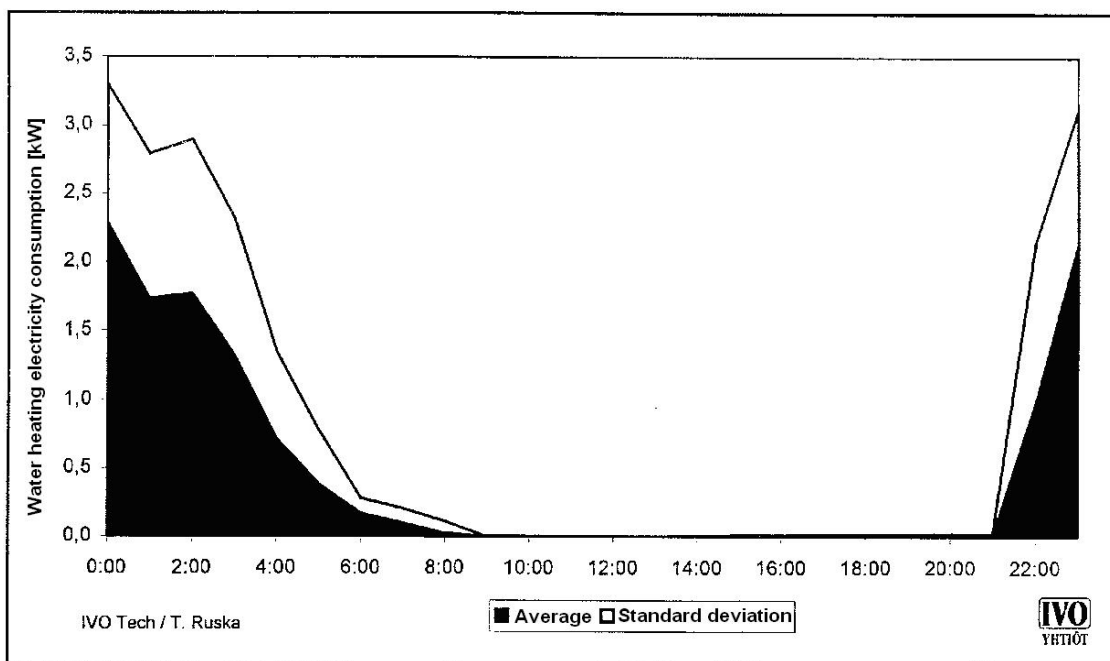


Figure 3 Average load profile for domestic hot water boilers (nominal power of 3 kW) in eleven houses.

Typically, consumers with water heaters are subject to Time-of-Use (ToU) tariffs. They can heat the water during the night and use it during the day for a lower price than if they were heating the water only when they needed it. That effect of the ToU tariff shows clearly in the load profile showed up here. It also illustrates that storage water heating has a very high ability to be shifted in time. We can also see that such flexibility could be available for demand response services only during the night, except if the need for demand response goes in the direction of an increase in consumption. It could for example make sense to turn on water heaters during the day in an area with a lot of wind power production in order to avoid congestion and having to turn off or down the wind turbines.

Water heating with storage is essentially a shiftable load. However, hot water tanks are not perfect and they suffer losses. The losses make it so that the total



energy consumption increases when the actual water heating is further in time from the use of the water. Water heaters are fully automated devices and could be controlled directly by the electricity companies or by some home automation system without any inconvenience for the users.

#### 2.2.2.2 Electric space heating systems

Space heating in the Finnish households is often provided by district heating (nearly always in the case of apartment buildings). Over 40 % of the detached and terraced houses are heated by electricity, Adato 2006 [37], see Figure 4.

In the new houses, the share of heat pumps increases. In 2007, over 20 % of the new houses were heated by ground-source heat-pumps.

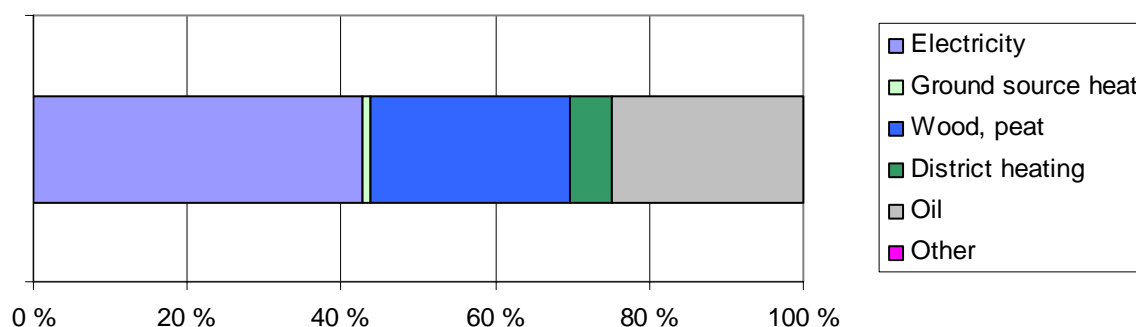


Figure 4 Heating systems of small Finnish residential houses, 2007 [31]

In Finnish households there are used basically the following three different main types of heat pump systems:

- Ground source heat pumps system for space and hot water heating. These are used both in new houses and in old oil-heated house to replace old oil-boilers.
- Ventilation and heat recovery with combined heating of fresh air and hot water production by heat pump. Basic space heating by direct electric heating (radiators or combination of room-specific heating elements).
- Outside air source heat pumps for additional space heating. Basic space heating is provided by direct electric heating (radiators or a combination of room-specific heating elements).

Space heating systems can be of three different types:

- Direct electric heating based on room radiators
- Partial storage heating where heat storage capacity exist in the building constructions or in the form of artificial storages
- Full storage heating

The full storage heating systems work by the same principles as water heating systems, but at a larger scale. The same boiler and tank is actually most often used at the same time for both purposes. The flexibility characteristics and the control options should be taken from the previous section. In the following, we will discuss only the case of direct heating systems.

Direct electric heating is controlled by thermostats. There can be one thermostat on each appliance (typical for radiators) or there can be only one controlling the heating of a single space. Thermostats can work based on two different control principles.

The first one is an ON/OFF principle. The thermostat is set to a temperature  $T$  by the user. The thermostat turns the heater on until the room temperature reaches  $T+\Delta T+$  (where  $\Delta T+$  is the upper part of a dead band necessary to the good functioning of the mechanical thermostat). It then turns the heaters off until the temperature reaches  $T-\Delta T-$  ( $\Delta T+$  and  $\Delta T-$  don't necessarily have the same value) when it turns back on.

The second principle is a P-controlled thermostat where the ON/OFF cycles last from some tens of seconds to minutes depending on the model. Heaters equipped with a P-controlled thermostat are not let on for too long periods of time and they are therefore preferred in situations where the heater's surface temperature shouldn't get too high.

Figure 5 shows the room temperature achieved with different types of thermostats. The electricity consumption goes so that the heater consumes the nominal power when the temperature is rising and doesn't consume anything when the room temperature is decreasing (with a delay due to inertia).

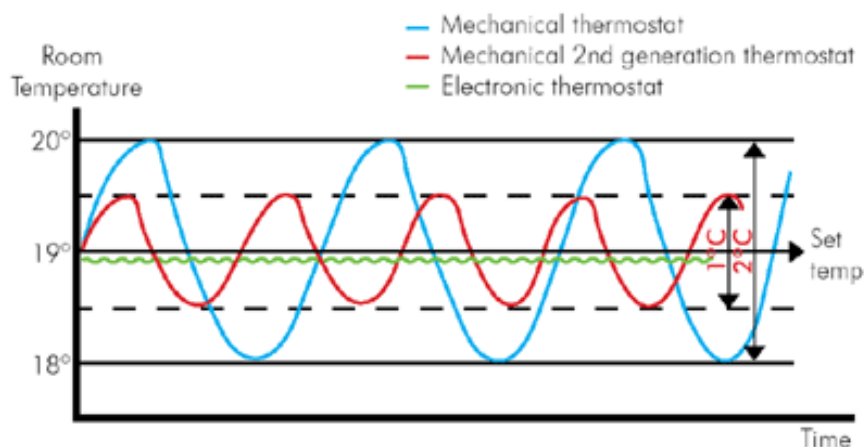


Figure 5 Room temperature with mechanical and electronic thermostats [53]

Heating systems represent a very large potential for demand response in Finland in winter (over 1GWh/h in day time, according to estimations made in [33]). Moreover, space heaters control wouldn't be very difficult to achieve by the consumers.

The first option is *manual control*. The consumers would receive a message and modify their thermostat's setting point accordingly. Such a signal could be sent by various means such as a light turning itself on or changing colour somewhere in the dwelling, an email, a text message on the phone or even on the television set or any other mean we can think of. Manual control however provides only slow responses and is more troublesome for the users.

The second option is *automatic control*. In this case, the users are not asked to change their setting point; it is made automatically based on a signal received either directly from the electricity company or through a home automation system. The most simple of these options was used some time ago in Finland. The electricity company sends a signal via the power lines to the heaters to turn them off when the power is needed and another signal to turn them back on later. With the advancement of technology and in a commercial situation, more advanced options become possible.

The automation system, or a smart thermostat, could receive price signals or interruption signals in advance and organize the consumption. For the consumers to accept the change in consumption, it is likely that they would require to keep a certain level of comfort. They could for example, in the thermostat, enter a minimum and a maximum allowable temperature in addition to the setting point. They could also assign an economical value to their loss of comfort in such a way that the thermostat modifies its control only if the price signals received provide an incentive higher than that established cost.

Space heating behaves mostly as a shiftable load. A reduction of consumed power for some time induces a decrease in the room temperature. When the control is set back to a normal operation, the heater will consume more power than it would have at the same time without the control action in order to bring the temperature back to normal. Researches and measurements indicate (Figure 6) that if the temperature is let to go down during the control action and restored later, the final energy consumption is reduced. We could hence say that a heating load is a shiftable load for a part and a curtailable load for the rest.

A smart thermostat could also increase the temperature prior to the control or high price signal in order to reduce the loss of comfort. The energy impact in such a case is more difficult to assess and would depend on how much over-heating is realized.

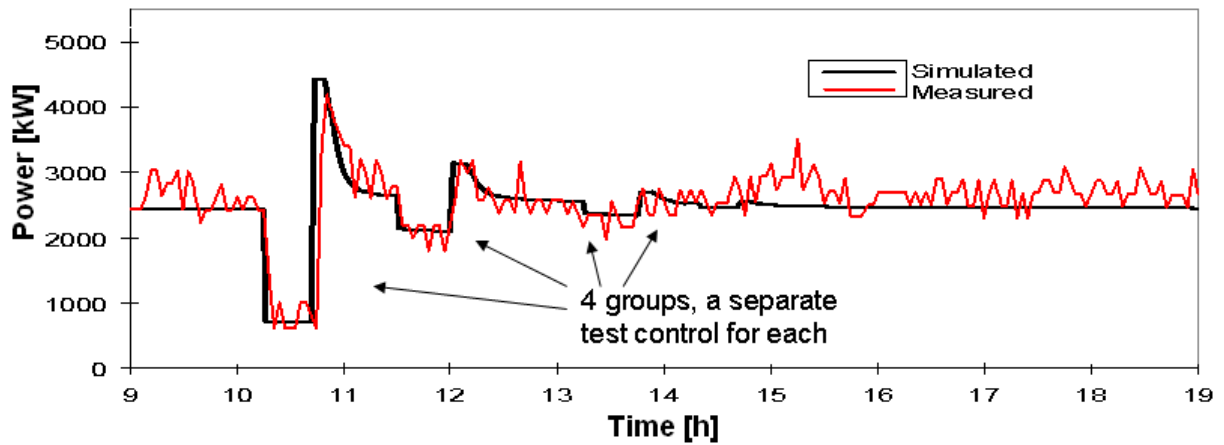


Figure 6 Measured and simulated consumption for 463 vacation houses submitted by direct control of their electric heaters. The measurement was conducted at the substation level, after the non-heating load profiles have been eliminated [32].

### 2.2.2.3 Air conditioning

Air conditioning is used very little in the Finnish residential sector, although its share is increasing. From a flexibility point of view, air conditioners offer the same capabilities as heating systems. They actually function following a principle very similar to the one used in heat pumps.

### 2.2.2.4 Sauna

Electric sauna is a direct heating load which produces higher temperatures and is turned on only when the sauna is required (as well as long enough before to make the sauna ready). These characteristics make that sauna is a bad candidate for direct control by the electricity companies or by some other fully automated means. Manual control could however still be quite adapted. Consumers may be encouraged to delay the start of their sauna time for a short period of time (probably up to a couple of hours) if they receive the proper signals and incentives. Such a control action would be made easier if a display or a signal is located near the on/off switch of the sauna. Saunas are shiftable loads.

The loss of comfort, and hence the cost, of delaying the start of a sauna could be not too important. On the other hand, an interruption during the sauna session would probably be seen as a much greater disturbance by the consumers. That type of control action wouldn't be impossible in all cases, but it would require a very high incentive.

### 2.2.2.5 White goods: washing appliances

We group in this category different types of appliances. We find here principally washing machines, dish washers and cloth dryers. They each achieve different results and work based on different principles, but they present the same characteristics in terms of usage and of flexibility.

Each of those machines has a working cycle that is divided into steps. For example, a washing machine typically has the following steps:

- Pre-washing
- Pre-heating
- Heating
- Maintenance
- Cooling
- Rinsing
- Spinning

Each step has different electricity consumption. In the case of a washing machine, most of the energy is consumed during the heating cycle, with a couple of short peaks during the pre-washing, the rinsing and the spinning steps.

These white goods are essentially shiftable loads. The easiest control system that could be performed is to delay the start of the working cycle. This can be done manually pretty much in the same way as for a sauna. It could also be automated. A display could suggest the user to delay the start when they program the machine. Some prototypes are developed where the user would input the time at which they wish the machine to be done and the machine would decide by itself at what type it should run based on electricity prices information. It would also be possible, in cases of emergency signals, to stop the cycle between some of the steps. In this case, some maximum delays could be imposed in order to guarantee the quality of the result (such as some anti-rumple function in a washing machine). In this case, the energy consumption of the machine is increased by the work due to these extra functions.

It is sometimes mentioned that appliances could be switched to a higher efficiency program (eco-program). Such programs save energy by using different techniques such as slower drum rotations or compensating a lower working temperature by a longer time of operation. We could however argue that for the sake of energy efficiency, such a program should already be used whenever possible and that this option shouldn't offer any potential for control.

#### 2.2.2.6 White goods: cold appliances

We find here fridges and freezers. These appliances are meant to keep some goods, usually aliments, under a predefined temperature. In general such appliances could not be used for flexibility without taking a risk of damaging the products that they store. Only short interruptions would be possible, but the device should always have the control over the inside temperature and should be able to override any control action.

In some cases, it would be possible to user pre-cooling techniques and force the temperature lower before a control action to allow it to last longer. Cold

appliances are however quite small loads in terms on power and the benefits from controlling them would be very limited.

#### 2.2.2.7 White goods: cooking appliances

Oven and cookers, pretty much like saunas, are used only when the user has a direct need for them. It could be possible, given the proper incentives, to postpone the start of the use. The loss of comfort in this case is very direct and the delay couldn't be too long.

#### 2.2.2.8 Consumer electronics

In this category, we find loads such as video and audio systems, computers, other office appliances, small kitchen electronics, etc. Imposing flexibility on such loads has a direct impact on the consumers' comfort. This is especially true for the entertainment units. . The compensation offered to the consumers should therefore be very important to convince them to offer flexibility by, for example, turning off their television or audio set. It could be slightly less important regarding kitchen electronics (cf. the cooking appliances).

Some electronic appliances have a battery (laptop computers, some music devices...). Those could offer some interruption without any disturbance for the user. The offered power would however be so small per appliance that it is probably not worth the trouble of considering them for demand response purposes.

#### 2.2.2.9 Lighting

Lighting has no storage capability and is used only when needed. Control actions on lighting systems could present risks for the safety of the users. Sophisticated control systems could dim the lights or turn them off in non crucial places when a signal is received. However often, if the lights could be turned down or off without any risk for the users, they should probably be so for the sake of energy efficiency.

#### 2.2.2.10 Electric vehicles

Electric vehicles are only starting to be a reality. In future scenarios, a large penetration of them would however cause large stresses in the electricity networks. There is a lot of research about the demand response capabilities of electric vehicles. Several charging methods can be identified [34]. In the first case, there are no control possibilities and the vehicle is simply plugged to the electricity system. In this situation, the user could still choose to manually plug the vehicle off or to activate a switch when a control signal is received. In the typical night and day tariffs, the user could plug the car only during the night or install a timed switch to do it for him. A home automation device could also control a car charging system.

In the second case, the vehicle's charger or the charging station, depending on the strategy used, could be linked to the electricity company or to the home automation system and organize its own charging planning according to the received information.

The third and fourth methods allow for the vehicle's battery to feed into the network or to sustain the home network in case of a black out. These cases require a high level of automation and of coordination with the network companies.

From a user's perspective, the type of connection probably matters little. What is important is the cost of the installation and the type of benefits that can be taken from it. The most important factor is that the vehicle should be charged satisfactorily when the user wants to use it. A system could be imagined in which the user would put in the time at which he wishes the battery to be charged and the charger would be free to choose how the battery is managed in the meanwhile. It should however be taken into account the user may have a change of plan or an emergency need for the vehicle. It would therefore be good that the vehicle tries to keep some minimum level of charge at all times, or as often as possible. This becomes a more important risk in the cases where the battery could feed power back into the network or to sustain an islanded (house) network (e.g. a house network).

## **2.3 Pricing and tariff structures**

### **2.3.1 Introduction and context**

In the context of this report, the terms *pricing and tariff structures* of electricity refer to the information that (residential) consumers receive regarding the cost of electricity services delivered to their residences. They are based on market, regulation and contracts arrangements, and impact, on the customer side, billing and metering, which have a clear dependence on available technology. The pricing and tariff structures can be assumed to have an impact on consumers' (and companies') behaviour related to electricity. Therefore, there are solid reasons to pay attention to pricing and tariff structures and their potential development needs and opportunities in the Smart Grid environment.

This section concentrates on the issues that Smart Grids bring upon tariff structure designs from a (residential) *consumer point of view*. The questions dealt with are

- (i) to describe potentially emerging options in tariff design due to Smart Grids
- (ii) to discuss the potential of new tariff structures in energy efficiency and demand response improvement
- (iii) identify related technology development and penetration prerequisites and
- (iv) identify barriers that potentially hinder the development.

The WP 5.2 of the SGEM program discusses tariff structures in a more detailed way especially from TSOs' and DSOs' business logics perspectives. These perspectives can also safely be assumed to be of significance for the successful implementation of the Smart Grid vision. However, the analysis presented in this section concentrates on customer viewpoint. General criteria for tariff design from various viewpoints are discussed in an article [24].

In addition to pricing and tariff structures, price levels undoubtedly have an effect on the future development and outcomes of Smart Grid visions. Estimations of future price levels of electricity, however, lie beyond the scope of this section. Some reference to the driving forces of price level development in the European context is made e.g. in the WP 5.3.2 of the SGEM program

### **2.3.2 Smart Grids and the altering foundations of tariff design**

The technological changes driven by a Smart Grid implementation and the degree of liberalization in the electricity markets will affect tariff design principles. The supply chain of electricity to end customers includes *generation, transmission, distribution, metering and billing, customer accounting, customer service etc.* The costs of all these activities have to be covered by the electricity bills paid by the end-use customers.

Ideally, according to classical theory of efficient pricing, the prices that consumers face should equal the marginal cost of electric service in order to make economically efficient energy-related decisions [27]. This is not reality in typical current pricing schemes. Being time and location dependent, the estimation of costs is not straightforward. For example, the costs for a distribution network designed to serve ten customers in an urban area will not be the same as for a network designed to serve the same ten customers in a rural area [28]. However, as will be shown later, advancements in metering technology and progress in market liberalization have enabled improvements, especially in capturing marginal costs of generation.

Traditionally, the whole supply chain of electricity has been handled by regulated utilities; however, there has been a trend towards more liberalized electricity markets throughout the world since the late 1980's. That is, generation and retail sales have been more and more often opened up to competition. This means that pricing is carried out by companies and determined market-based according to supply and demand. Distribution and (high-voltage) transmission, on the other hand, are considered natural monopolies<sup>1</sup>. Hence, pricing is regulated by authorities to cover the costs of activities. On the consumer side, these services

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<sup>1</sup> In a case of natural monopoly, it is economical for a single company to supply a given service instead of two or more competing. This has been considered to be the case in electricity transmission and distribution. However, the most effective arrangement of electricity industry may change in the course of time driven by technology development. There is a need for efficient regulation for natural monopolies discussed e.g. in an article (Rodriguez Ortega et al. 2008).



are compensated by paying electricity bills, which can present various company-specific, country-specific or contract type-specific forms. Typical components are network tariffs (i.e. distribution tariffs) and retail tariffs (i.e. energy tariffs). Also, fixed monthly basic customer charge may be included in the bill, in addition to components caused by taxes.

Technological, organizational and market liberalization development enforced by Smart Grids may bring totally new type of actors in the electricity markets. *Aggregators* are an often discussed type of new actors that would collect aggregated loads from small customers and bid them into the market. However, the vision of such new participants entering the electricity markets requires technological change in traditional electricity infrastructure and, probably, in the tariff and pricing systems, too.

The most significant changes in pricing and tariff structures arising from Smart Grids would most notably concern small-scale residential customers. These include firstly dynamic pricing options, reflecting more accurately and time-dependently the underlying costs of electricity generation and, secondly, price-responsive load management options, possibly relying on advanced automation and sensor technologies. Industrial and commercial customers, who have consumption levels large enough to cover the costs of additional metering and load management technologies also on today's price levels, typically already have adopted such pricing and technological options to greater extent.

### **2.3.3 Dynamic pricing**

Smart Grids provide enhanced options of pricing and tariff structures. In traditional grid infrastructure, pricing of electricity and network services has little or no relation to the real-time electricity network or generation conditions. The short-term conditions that influence generation costs and wholesale prices to some extent are not reflected in the prices paid by consumers. This is due to the fact that tariffs paid by the customers for kilowatt-hours used by them are fixed in advance and typically updated rarely, e.g. once a year. This kind of traditional tariff structure is referred to as flat rates. Dynamic pricing, on the contrary, can capture wholesale electricity market prices with an hourly or even higher resolution.

Dynamic pricing requires advanced metering, which is an essential part of the Smart Grids vision. Discussion of introduction of dynamic tariffs often relates to retail (energy) tariffs. However, new tariff methodology options enabled by Smart Grids could also relate to distribution tariffs. General distribution tariff methodology and new approaches are discussed e.g. in an article by Rodriguez Ortega et al. 2008 [28]. Introduction of dynamic distribution tariffs, however, is not straightforward due to the fact that distribution of electricity is - at least for nowadays - regulated activity. Price formation should be transparent and regulable by electricity market authorities.

Typical time-varying price structures include Time of Use (ToU) tariffs, real-time pricing (RTP) and Critical peak pricing (CPP). RTP and CPP can be truly dynamic pricing options due to their potential dependence on wholesale prices. The degree of dynamics can be the largest in RTP - prices can vary with an hourly resolution and be based on the wholesale market prices. Under ToU, the consumer price varies in a preset way within certain blocks of time. The CPP price structure presents a more recent innovative addition to the ToU price structure. That is, in CPP the ToU-like structure is completed by one more price level concerning “critical” peak hours, which the utility can call on a short notice. The number of critical peak hours is typically limited to 50 or 100 hours a year [19]. More thorough description of different options is included e.g. in National Action Plan for Energy Efficiency, 2009 [60]. For example, Peak Time Rebate (PTR) is a tariff structure, where customers who reduce electricity use below normal on critical peak days would be offered a rebate.

In a properly functioning electricity market, dynamic pricing provides stronger incentives for demand response and peak shaving measures taken by consumers. For example, information of supply shortages or scarce network conditions can be reflected to customers (near) real-time as higher prices. Compared to flat-rate pricing, varying prices motivate the customer to adjust his/her electricity use. That is, the consumer has an incentive to shift the electricity use to lower-priced periods, which reflect less tight supply-demand balance in electricity markets.

Implementation of dynamic pricing and more accurate information brought by it potentially benefits not only the consumer but the whole system. Dynamic pricing may lower investment needs for electricity companies and grid operators and cost of electricity for customers. Potential cost benefits also include operational short-term costs of power regulation. Naturally, the costs of implementation of dynamic pricing schemes must be overtaken by the benefits.

Advanced meters are a necessary precondition to implement dynamic pricing, see chapter 2.4. Advanced metering is an essential part of Smart Grid concepts. Therefore, compared to traditional grids, implementation of Smart Grids provides enhanced options for dynamic pricing schemes to be introduced for customers. This has an essential impact on realisation of peak power reduction and load-shaping potential. Only recently have advanced meters started becoming more common. Therefore, experience of advanced real-time pricing is restricted to pilot projects implemented in the last few years.

To realize the potential of dynamic pricing from the consumer point of view, consumers must be informed enough to take effective energy efficiency and demand response measures. There are deficiencies with regards to in the traditional grid infrastructure. On the other hand, feedback must be kept simple to be understandable. This is related to improvement in consumer feedback of electricity enabled by Smart Grids discussed in the following section.

### 2.3.3.1 Technologies that support dynamic pricing

Electricity companies' feedback to the consumers includes price and/or consumption levels related to their electricity usage. An example of the feedback in a context of traditional grids is the electricity bill. Typically, the bill is initially based on estimations and balanced according to meter readings of electricity consumption of a whole household once a year. Thus, typical feedback to consumer in a context of traditional grids can be characterized as sparse, inaccurate and static. By increasing the awareness of customers about electricity usage and prices, an improvement in the feedback presents a potential to strengthen the benefits of dynamic pricing by providing the customer better possibilities to response to real-time signals.

Visions of Smart Grids include enhanced options for the improved real-time feedback to consumers. Improved feedback provides consumers with more accurate and up-to-date information on price and/or consumption of electricity through different interface options. Building on advanced metering and modern communication technologies, discussed options of the new feedback methods include internet, e-mail, mobile phones, Pop-Up windows appearing on television screen, etc.

A relatively new type of the customer's interface device called in-home display transmits real-time information of customer's electricity usage (price and/or quantity). Currently commercial models and prototypes of in-home displays and results of their field tests are described in Similä & Pihala 2010 [29]. The most common present commercial models work independently of the grid, i.e. also in traditional grid infrastructure. In-home displays of this type can be described as being conventional technology. The possibilities of these devices to unleash the potential of dynamic pricing are limited. See some examples of in-home displays in Figure 7.

Having well designed displays accompanying smart meters is a key to the objective of saving energy, saving carbon, saving money for householders [44].

A report on in-home displays [29][18] summarizes some important points found out in some pilot experiments and to be considered in planning those displays:

- Changing values are poorly noticed by numeric displays.
- Keep it simple. Increasing information always caused resistance.
- Mobility is valued, but for a limited period.
- Different users have similar needs. Differences between the user groups did not lead to fundamentally different solutions.



Figure 7 Examples of in-house displays [18].

Advanced in-home-displays enable two-way communication between customer and electricity utilities. The options include transferring of dynamic price information to be displayed in real-time on the in-home-display. Advanced in-home-displays that are compatible with advanced metering infrastructure have only during the last couple of years achieved piloting phase. In the future, technological progress towards appliance-specific consumer feedback, possibly processed, may further increase customers' awareness and thus enhance the effects of dynamic pricing.

Smart Grids may enable even larger possibilities for energy efficiency and demand response improvement. Automatic control of appliances, automatic demand response and integration of building-specific small-scale generation to the grid are examples extending beyond dynamic pricing and improved consumer feedback. There is a need for technology development, demonstration and penetration as well as pricing improvement to realize these options. Enabling technologies include advanced sensors, communication technologies, data management and "Smart Appliances", which can be automatically controlled according to price signals. Applied to electric cars, smart technology enables smart charging of electricity vehicles, i.e. the charging is scheduled at low-cost hours. "Smart Homes", correspondingly, refer to building concept under development and pilot phase. In Smart Homes, the whole building is controlled by smart technology, where appliances are connected to a local area network (LAN). The feedback type including advanced automation solutions have been called "real-time plus", [20].

### 2.3.3.2 Barriers and customer acceptance of the dynamic pricing

The Smart Grid concept will most probably bring changes in the pricing and tariff structures proposed to consumers, taking them closer to real-time and dynamic pricing. Increased price elasticity of demand has an impact on market prices, which can benefit all electricity users. Pricing and tariff structure changes are, as is typical in the energy sector, characterized by a certain inertia due partly to long technical life-times and a capital intensity of the infrastructure.

One natural requirement for customers to favour such a change is the resulting economic benefit. A relevant question that arises is, whether economic benefit for different households provides motivation strong enough to actively adjust their electricity usage according to price signals. For example, a typical energy and distribution part of electricity bill of two-room flat in Finnish apartment house lies in the order of a couple of hundreds of Euros per year. Even if we would optimistically assume that improvement brought by Smart Grids would bring energy savings of dozens of percents, it is not self-evident that customers are willing to substitute the comfort of freedom of time-independent usability of appliances for financial compensation of this scale. However, there might be differences in customers' willingness to trade-off between freedom of use and economic benefit according to appliance group and type of management. The preferences of customer groups, also, may have an influence on penetration of renewal of tariff structures. For example, environmentally concerned customers may favour efficiency improvement opportunities enabled by smart grids more than average customers, even there would not be direct short-term financial benefit.

In Finnish conditions, the largest-scale residential electricity consumers typically are equipped with electrical heating. Large-scale households face electricity bills roughly larger to a factor of ten and, therefore, enjoy potentially higher incentives. If electricity prices continue to rise, it will increase the potential benefits of energy efficiency improvements and of other options reducing the amounts on the energy bill. For utilities the benefits include lower investments in peak-load capacity and in grid development. These may spread to benefit the consumers, too. Furthermore, automatic load control removes the burden from the customers to actively follow the price level and respond to it.

The impact of the introduction of real-time pricing for customers depends on their load profiles. That is, customers with high peak-load would face a higher increase in electricity costs than customers with flatter profile. This can imply resistance among consumers with high peak-load to accept the tariff changes from flat rates towards real-time pricing.

## 2.4 Smart metering

Smart electricity grids and demand response are potential ways for achieving the national and EU targets in mitigating the CO<sub>2</sub> emissions. Other related reasons are improving the electricity retail markets and reducing the need to invest to network and peak power and reserve generation. Smart metering, also called advanced metering infrastructure AMI, is one of the enablers of the future Smart Grids and demand response [36]. This requires metering systems that can at low cost provide adequate data to the systems and services.

The aim is to measure hourly energy consumption. The functionalities that need support from the metering systems include:

- provision of metered data for balance settlement in the electricity markets
- customer information services
- power quality monitoring
- load control and demand response
- energy feedback and saving
- load and response modelling.

Home Area Networks (HAN) and other local networks need to meet certain requirements in order to properly enable smart metering, energy saving, demand response and Smart Grid applications. The following requirements are typically mentioned:

- supported by a reliable certification process
- secure two way communication
- supports both direct load control and price control
- direct immediate access to nearly real time consumption data

It is necessary that the interfaces of smart metering systems are compatible with European and National legislation regarding privacy [36].

Finnish Council of State has given decree 66/2009 on electricity distribution and measurement. It states that all electricity consumption points shall be equipped with remote measuring devices capable of measuring hourly consumption. This kind of measuring device is not compulsory in the electricity consumption points equipped with main fuses less than 3x25 A, if the consumption can be estimated accurate enough [62].

The target is that in the end of 2013 at least 80 % of customers of distribution networks have remotely and hourly measuring electricity meters. A customer can separately order an hourly measuring device equipped with a standardized coupling for real time electric energy monitoring. Legislation in Sweden presumes that all electricity consumption points having main fuses of 3x63 A and above

shall be equipped with hourly recording meters and those below shall be charged based on monthly reading [38].

As a conclusion of Pricing and tariff structures as well as smart metering it may be stated:

1. Pricing must provide incentives to manage energy use more efficiently and enable consumers to save money.
2. Communication Standards must be open, flexible, secure, and limited in number.
3. Consumer Choice & Privacy must be respected; the consumer is the decision maker.

Important features for meters like accurate and reliable measurement; confirmed data security and integrity; privacy etc. have been set or recommended in Europe. Those features are not generally followed [38].

Smart Metering Landscape in Finland is presented in the report [63]. Utilities have started implementing their Smart Meter rollouts swiftly, with well over 1 million meters at place (with around 2 million left to be installed). The most important question at this point is: is the huge amount of metering data coming from end-users (now stored by DSOs) available to all relevant actors who can make end user services (and energy savings) with it, and at what cost and restrictions? Who will pay the better service and who will pay for the new building systems integrated to the meter and related controls - and when will these services and technologies reach the end-user masses?

## 2.5 Actor network in the system

Several different actors can be involved in providing consumers with the electricity they wish to consume. Based on the EU Internal Electricity Markets (IEM) Directive 2003/54/EC the distribution and transmission of electricity on the network must be clearly separated from the production and retail activities. Figure 8 shows the different actors and the basic exchanges between them. We can see there the difference between the commercial transactions, how electricity is sold from the producer to the final consumers, and the physical transactions, how electricity is actually delivered to the consumers. Some transactions and some actors are missing from this figure. The purpose here is to illustrate the general principle and to start the discussion. The ways the system operators are remunerated from the other actors are for example not showed.

We will now go into more details about each of the actors, their roles and responsibilities.

We should keep in mind that a single actor can have several roles. More specifically the same entity can act as producer and retailer and even potentially as a balancing responsible party and an aggregator. In the descriptions below we consider an actor taking up only a single role.

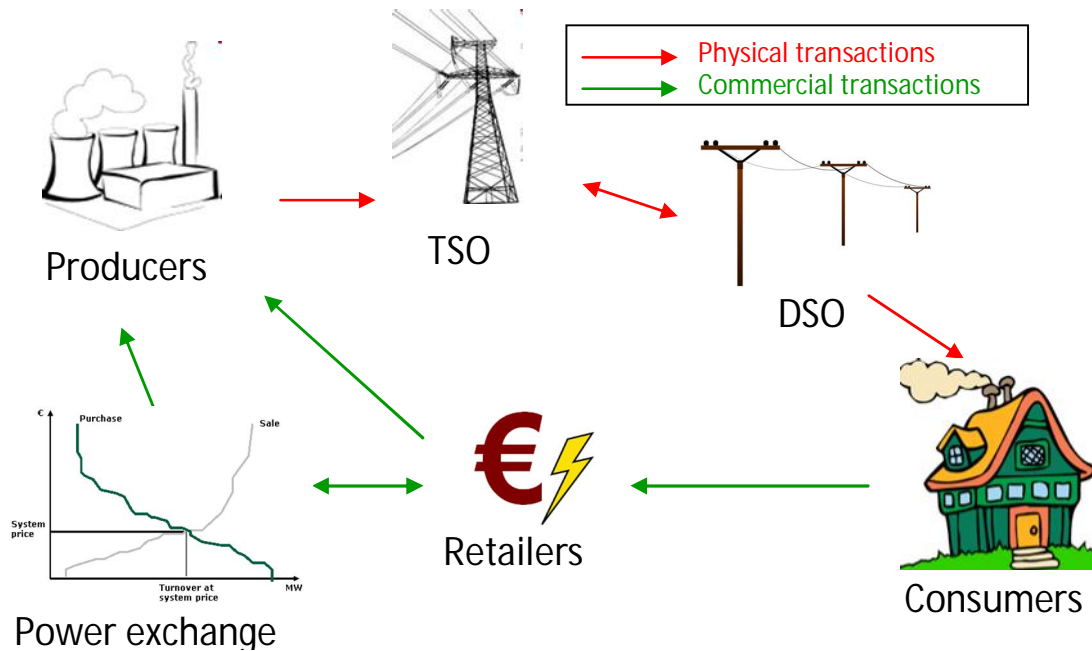


Figure 8 Actors in the electricity business

### 2.5.1 Electricity producers

Electricity producers, as their name states, produce electricity. The electricity is produced from different sources such as nuclear fission, fuel combustion, water, wind or sun. In Finland in 2008 the production amounted to 87.2 TWh of which about 40 % was obtained from fuel (gas, oil, coal, biomass) combustion, 25% from nuclear fission, 20 % from hydropower and 0.3 % from wind turbines [39].

The producers can sell the produced power either on the power exchange or directly to retailers. Producers are also often retailers themselves. Physically the electricity is most often delivered on the transmission network. In the case of small production units, such as wind mills, solar panels or small Combined Heat and Power (CHP) installations the delivery is made on the distribution network.

The objective of the electricity producers is to maximize their profit. Their incomes come from selling electricity on the power exchange, directly to retailers or from offering services to the TSO. Their expenses include principally operational costs, fuel costs when applicable and the costs due to changes between the scheduled and the realized production. These can be referred to as balancing costs. The balancing issues will be discussed in the section about the balancing responsible parties.

For large producers, directly connected to the transmission network, Smart Grids will have little impact. It can be very different however from small producers. Small producers that are connected to the distribution network will have to interact with the Smart Grid operation. We should make a distinction between two types of small producers.



Some small producers have a very good control on their production. It is the case for example for owners of distributed Diesel generators. Such producers could be a very valuable asset for Smart Grids. They could offer services in the form of increases or decreases of production and help alleviate some network constraints.

On the other hand we have so called "uncontrollable" distributed generation. We find here typically isolated wind turbines (large wind farms are often connected to the high voltage network) or distributed solar panels. These producers lack the flexibility of the previous ones. They produce when the energy source (wind or sun) is available. There is of course the possibility of curtailing their output or of turning them off in case of network trouble but the EU and national policies push towards an increased production from renewable sources. Increasing the penetration of distributed generation is also one of the major drivers towards Smart Grids. In a Smart Grid context this uncontrollable generation is one of the most important trouble makers.

Combined heat and power (CHP) units are often controlled according to the installation's instantaneous heat demand. From an electrical point of view their behaviour would bring them in the "uncontrollable" category. Units with heat storage capacity could however be, to some extent, controlled according to the electricity needs and fall into the controllable category.

### **2.5.2 Transmission System Operator (TSO)**

The transmission system operator, or TSO, is responsible for making physically possible the transport of power from the producers to the consumers at the high voltage (110kV, 220kV and 400kV in Finland) level [41]. The TSO in Finland is Fingrid Oyj. Large producing units are connected directly to the transmission network as well as some very large consumers (large industries). Small producing units and most consumers are connected to the medium or low voltage network which, itself is connected to the transmission network.

The TSO role involves several activities. The first is to set, organise and maintain the power exchange (see the chapter power exchange below). The second is to keep the system balanced (see the chapter balancing responsible party below). Other activities include the maintenance of the voltage level (by controlling the reactive power production and consumption), the maintenance and upgrading of the transmission power lines, the allocation of capacity on the interconnections with the neighbouring transmission systems and the deliverance of certificates (e.g. guarantee of origin certificates for renewable energy sources in Finland) .

The maintenance of the voltage level would have a priori a very limited impact on the Smart Grid operation. We could however imagine that the TSO would transfer a part of its responsibility on the Smart Grid and limit the reactive power that the Smart Grid is allowed to produce or consume. The TSO already imposes limits to producers and consumers directly connected to the transmission

network. Most commonly the reactive power level is controlled by adjusting capacitor banks, sources of reactive power.

Maintaining and upgrading the power lines is based on the maximum power transfers on the transmission network. The need for upgrading could be slowed by the arrival of Smart Grids and other distributed resources. If more power is produced where and when it is consumed the need for high voltage transmission is reduced and thus the congestions at the transmission level become less common and upgrading the lines can be delayed.

It should be noted that the TSO's role as guarantor of the system's stability is extremely important and that the inclusion of Smart Grid concepts and of flexible distributed resources to the system operations should be considered very carefully. If there is a chance that the Smart Grid or the distributed resource isn't going to perform according to the TSO standards the TSO will not be willing to interact with it.

The TSO should also be an independent actor and treat all the other actors fairly. This is due to the fact that the transmission activities are a natural monopoly and that TSOs are thus regulated actors providing a public service.

### **2.5.3 Distribution System Operator (DSO)**

The role of the DSO is to operate the distribution (low voltage) network. It should "guarantee access to the network for all users, applying objective, transparent, and non-discriminatory standards" [42]. In the same way as for the TSO, the DSO business is a natural monopoly and thus falls in the category of public services. That is to say that DSOs are regulated actors. In practise it means that the regulator gives guidelines as to how, based on its costs, a DSO can fix its distribution fees.

Distribution system operators will be major actors in the Smart Grid development. A Smart Grid would typically be a section of the distribution network that is coordinated and that cannot be done without the participation of the DSO. The DSO would probably have to be the actor who centralizes the information and sets up the local exchange possibilities. In situations where the distribution network is subject to physical constraints the traditional way of handling it is to upgrade the network. With Smart Grids and flexible resources the DSO could call upon those resources to solve the contingency. There is however a concern here due to the fact that the DSO should provide a fair and non-discriminatory treatment to all actors. The way the DSO will interact with distributed resources (generation or consumers) should be designed very carefully in order to ensure that the service provision remains cost effective and that that the DSO doesn't give an unfair advantage to some retailer or producer compared to the others.

#### **2.5.4 Power exchange**

The power exchange is a platform on which electricity can be sold or bought. In the Nordic countries the power exchange is called Nord Pool Spot. Electricity can also be traded by the actors directly among each other without going on the power exchange. Nord Pool Spot however registers exchanges for over 70% of the total consumption in the Nordic countries [40]. The exchanges take place on Nord Pool Spot on a day-ahead basis as well as intra-day, up to one hour before the delivery. On the day-ahead basis the participants send offers for consumption or production before noon for the following day. The power exchange aggregates those bids to form supply and demand curves and sets the market price accordingly.

The objective of a power exchange is to allow and encourage fair, transparent and cost reflecting prices. Thus the organization of such a market should be handled by a regulated actor and, as mentioned earlier, it is in most countries done by the TSO.

Currently power exchanges in Europe are mostly national or international entities. There are however often mechanisms to split the market to a more local level. Norway can for example be split into five zones with different market prices. The zones are defined depending on the transmission network limitations. The need for splitting is encountered when the power that would physically be exchanged between two zones becomes too important for the electric lines to handle.

From a Smart Grid perspective the DSO could organize its own market at a very local level. Such a local market could be obtained by splitting from the existing power exchanges, or connected local markets could interact and sell or buy power from each other in the limits of the physical connections.

The terms employed for cutting a market into smaller parts and for having markets interacting with each other are respectively "market splitting" and "market coupling". They both are ways of handling interconnection limitations and should both yield the exact same market results. Because the interconnection limitations are not traded directly such systems are referred to as "implicit auctions" while direct trading of interconnection capacity is called "explicit auction".

#### **2.5.5 Retailers**

A retailer's role is to provide electricity to the consumers. A retailer must produce itself or buy from other actors the electricity that he is selling to the consumers. As we have seen the actual transport of power from one place to another is taken care of by the TSO and DSO. Retailers are not regulated players and consumers can freely switch from one to another. The objective here being to encourage competition and to bring prices down. Retailers are responsible for their own

balance either directly or via a balancing responsible party. The balancing concept will be explained when we discuss the balancing responsible parties.

At this date the regulator Energiamarkkinavirasto (Energy Market Authority) knows of 74 energy retailers in Finland [43]. However there could be more of them since the retailing activity doesn't require a license. There can be retailers that do not show on their list.

Retailers are the best suited actors for interactions with the consumers. Demand response and other distributed resources could very easily fit into the retailers' portfolio. Having two different actors, one for the retail activities and one for managing the flexible resources would actually bring in quite many issues such as sharing the responsibility for imbalances or for a failure to deliver a specified service.

A retailer using flexible resources to offer service is often called an aggregator. The aggregator would be the link between the consumers or the owners of other resources and the service buyers such as the TSO, DSO or balancing responsible parties. A retailer with flexible resources could also use these in order to reduce its production costs or to avoid having to buy electricity on the markets when the prices are high.

In the Smart Grid context the retailer would be a service provider for the DSO. But here again the fairness that the DSO must show towards the different actors should be considered carefully. The way the DSO chooses from which retailer it buys services should be transparent and open to other retailers or other potential providers of the same service.

### **2.5.6 Consumers**

There are different types of consumers with different needs and different behaviours. Consumers with higher energy consumption would tend to be ready to invest more in energy efficiency and in demand response capabilities. Some large industries already offer demand response services to the TSO.

Consumers have relationships with a DSO and with a retailer. The DSO is fixed and related to the location, but the retailer can be chosen among all the retailers active in the area (the whole Finland for example is a single retailing area). The billing should make that distinction clear. However in Finland consumers who haven't switched their retailer after the market liberalization can have the network and energy fees on a single bill.

### **2.5.7 Balancing Responsible Parties (BRP)**

The BRP doesn't appear in Figure 8. The reason for this is that its role is related to system security. It influences on and interacts with the other actors but we left it out for the sake of clarity.

All actors trading electricity (mostly producers and retailers) must declare it to an entity called a Balance Responsible Party (BRP). In Finland there are 31 BRPs, most of which are also producers and /or retailers. The BRP gathers the declarations and must make sure that its declared energy production is equal to the declared consumption. After the delivery the realized production and consumption are measured or evaluated. If the production and consumption do not match, the difference is called an imbalance. Correcting those imbalances is the responsibility of the TSO. But it has a cost which the TSO allocates to the BRPs and they in turn pass it on to the producers and retailers. In this way all retailers and producers are encouraged to stick to their forecasted production and consumption values.

In Finland the balancing is assessed on a one hour basis. This means that the BRP has to pay imbalance fees for the difference between its energy production and consumption during each hour of the day. A BRP could be a very good customer for demand response or other flexible resources providers. A BRP could use those resources to improve its balance and reduce the balancing fees it has to pay.

The balancing at the TSO level is made through direct contracts between the TSO and producers or through a balancing market. A balancing market allows the owners of flexible units to offer to the TSO to adjust their production or consumption in order to help keep the system balanced. The TSO of course pays them for that and that constitutes most of the balancing costs for the TSO. The TSO has very strict requirements for participating to the balancing market (minimum volume, short time between service call and activation...). Only large producers and very large consumers are nowadays able to meet those requirements.

### **3 Exploring consumers' opinions and expectations**

#### **3.1 Investigation on customer service interactions in Finland and Sweden**

Consumers' opinions and expectations concerning their usage of electricity and smart grid and smart house technology were explored in the context of customer service of an electricity company in Finland and Sweden. The phone contacts are mainly handled by the agents of the customer interaction and service (CIS) department of the company.

The goal of the study was to find the consumers' areas of interest and the customer service agents' experiences on customers' problems by exploring the information exchanges between the customers and the customer service agents.

##### **3.1.1 Analysis of statistics and interviews of customer service agents**

In order to find problem areas and areas of interest to customers, incoming phone contacts to the company's CIS department in Sweden were analysed. Different categories of phone calls, a total of 54000 calls during a period of seven first months of 2010, were grouped according to the functionality or association to different processes within the company. By sorting out the regular, routine calls customers must make for different reasons two major groups appeared: "forced contact" that represents 55% and "Investigative contact" that represents about 45% of the total calls. The main group "forced contact" represents calls the customers more or less must make, there is a distinct matter which must be solved in relation to invoicing, agreements and maintained electricity supply.

The rest of the calls were labelled "investigative contact"; the customer makes the call in order to gain knowledge, sometimes used as base for future decisions related to electricity agreements or the electric installation. The electric installation considers in this text, the electrical material in close connection to the point of connection such as the main fuse, the electricity meter and incoming power cable. Both of the major groups of calls are interesting in their own way and both could be solved to some extent by technological solutions.

Within the major category, forced contact, the largest portions are contacts concerning moving, invoicing - payment and complementing information for invoicing. The largest sub-categories within the group of investigative calls are questions regarding electricity prices and changing supplier, 38 %, explaining the invoice, 15 %, and questions regarding the electric installation represent 14 % of the calls. Questions regarding electricity consumption represent 8 % of the calls made to check something up when the calls for forced contact are subtracted. Besides this there are also the calls made directly to the energy guidance group.

Freeform interviews regarding incoming customer contacts and the customers' interest and knowledge regarding smart grid and smart house technology were

conducted in Sweden and Finland by using the customer service agents as interviewees. A total of 15 agents were interviewed. The main goal was to find new angles towards and points of views regarding customers' knowledge about and opinions on the electricity supply system and electricity usage; what are the typical questions or problems of the customers? The most frequently given opinions and answers considered to be of most significance to the scope of this study are presented as results.

### **3.1.2 Questions concerning electricity agreements, bills and disturbances in distribution**

Regarding electricity agreements customers often say that there are too many different tariffs and companies to choose between and customers try to find out whether the current price is competitive. This category is closely related to questions about consumption. Customers often ask for a better electricity price when they are not really aware or not interested in the potential of saving money on lowering their consumption instead. A high number of calls regarding the electric installation indicate that people generally have a low knowledge about the electric installation. From these discussions it was apparent that people generally have a low level of knowledge about what is their area of responsibility concerning safety issues and ownership. Customers are also uncertain about the information given on their electricity bill. This seems to be a result of people not being clear about the difference between electricity and distribution fees. Two separate bills make it hard to follow the total costs for consumed electricity.

Questions regarding disturbances were discussed with seven of the agents. Most agents said that when people loose electricity supply and call in they want to know why there is an interruption, what caused it and how long the interruption will last. Some customers call in several times during longer interruptions, to find out how the work is progressing. Many customers express dissatisfaction about the fact that the electricity company is not always aware of outages or disturbances until the customers inform the company about them. Customers expect the grid owner to have better control over the grid by use of modern technological solutions.

### **3.1.3 Questions regarding electricity usage and smart house technology**

In matters of electricity consumption customers mainly try to take other measures prior to looking over their own consumption habits. Changing electricity retailer, trying to change main fuse in order to get a lower bill or denying the consumption by blaming the meter for being faulty are usual occurrences. Most customers are not very fond of relating their consumption to their personal behaviour. Whether the customer is willing to accept new information about this subject varies and according to the agents it is often easier to start the discussion when the customers have already been following their consumption for a while. In that case customers have become aware of the size of their electricity consumption and are more interested in finding out how to make changes.

The main question when people realize that they can affect their consumption and start to get involved is which appliances contribute to which amount of consumption. They start to ask questions about how much electricity different appliances use and how many different changes actually will affect their total consumption, where in their house different amounts of electricity are consumed and whether that can be changed. When asked, most agents said that customers generally have low insight on which appliances they have in their homes and how much electricity different appliances consume.

The customers' interest in producing and feeding electricity to the grid was widely discussed. Most questions about this concerns wind or solar power and customers are interested in knowing if it is allowed to connect DG units to the grid and if it is possible to sell their excess electricity to the grid. Farm owners are a large group with interest in producing own electricity, aiming at security of supply and lowering total consumption.

Due to the fact that the AMM meters were quite recently employed and play a central role in many smart grid discussions the customers opinions and reactions towards these were carefully discussed. Most questions directly concerning the meter were about how often readings are done and generally about their functionality. The overall opinion of the agents was that customers have become more aware, if not of their actual consumption, but at least of the ordinary level of their monthly cost. What customers ask for in future development is acquiring more meter readings; daily, hourly and real time values. Several agents said that customers also ask for the possibility to see where electricity is consumed, which unit has consumed how much. Several customers expect more of the display and ask for further developed information.

#### **3.1.4 Reflections on the results**

One interesting fact clearly appearing from the statistics concerning the phone calls and conversations with the CIS agents is the number of people calling to check things up. There is a great need for being assured that bills actually have been paid, what is going on in the power grid regarding service work, disturbances in power delivery and often just to find out what is going on with the electricity grid.

The electricity grid is a system that has been owned by the government and many people still see electricity as a civil right. That is not the case anymore. There is a free electricity market and grid areas are mainly owned by competitive companies. Customers are often curious about how the grid is built and call in to find out if service work is going on within the grid.

Customers are often reporting problems and areas that, they consider, are in need of service and updating. They are also often interested in providing information on where new houses are planned and how it would be profitable to plan for new grid. This is information that could be valuable to the grid owner and



could, to some extent, be utilized for long term planning. But a system for collecting this information is needed.

When comparing the interviews conducted at CIS, Finland and Sweden it was noticed that the agents' answers were very similar to each other and the agents seemed to experience the customers and their questions equally. But there were still some outstanding deviations.

The most apparent difference between the countries is the fact that Swedish customers have AMM meters installed and receive electricity bills based on real monthly consumption while AMM meters were soon to be implemented in Finland at the time of interviews. When discussing customers questions regarding everyday energy consumption there were no distinct differences between the countries. A vague difference could be that the Finnish agents were more focused on how personal behaviours and habits affect consumption, while Swedish agents were more focused on different heating systems in houses and outdoor temperature. A clear fact is also that the Finnish agents have a lot of sorting out and explaining to do before the customers are clear on the size of their consumption. Swedish customers, on the other hand, get information about their exact consumption per month and the agents can start the discussions from there.

Based on the discussions regarding power outages it seems like Finnish customers have a lower tolerance towards disruptions in the electricity delivery and especially the duration of disruptions. This could be due to the fact that there is a higher level of automation in the Finnish grid and Finnish people are used to a continuous electricity delivery and fast recovery.

## **3.2 Inquiries on consumers' opinions and expectations in Finland**

### **3.2.1 Background**

The Association of Home Appliance Manufacturers, AHAM has represented requirements for achieving acceptance on Smart Grids. One important feature is to allow consumers to better manage their electric energy costs. AHAM's objective is to make the interaction as simple and effective as possible for the consumer [17].

The project HEAT'07 [26] was coordinated by SYKE, Finnish Environment Institute and it was designed to improve household energy efficiency and mitigation of climate change impacts. Important goals were to improve the means available for consumers to get information on their electricity consumption and to test the real-time measurement with a user interface in the project.

The HEAT project was started by selecting ten pilot households. The background information, the appliances and the routines of these households were first inquired in detail. During the test period of almost one month the experiences of the interface and the influence of information on the consumption were collected.

After the test period the pilot households were asked for the feedback. In general, the households found the system interesting but large electric energy savings in their homes are not possible due to their relatively small total consumption. The tested system operated technically quite well. Still only few pilot households believed that their electricity consumption would decrease. In the project hour-based and minute-by-minute measuring was compared. It was noticed that an hour-based metering gives enough information for the households decision making.

The report Household Energy Awareness Technologies 2007 - Results of the project HEAT'07 [26] pointed out the importance of a good feedback. An efficient feedback shall be given immediately and it shall be directed the consumer. The possibility to compare the readings to the earlier consumption helps in understanding the feedback and responding to the changes. Quite many factors have an influence on the energy consumption on the households; buildings, electrical devices and users.

Developing household-level energy measurement into an hour or minute-based system enables better cost dependence in energy pricing, enabling the electricity cost for households to accurately reflect the actual cost of the electricity production. This should strongly influence individual energy consumption habits and the resulting environmental impacts [26].

The Smart-A project "Smart Domestic Appliances in Sustainable Energy Systems" aimed at developing strategies on how smart domestic appliances can contribute to load management in future energy systems [21]. The analysis was based on the survey performed in five European countries: Austria, Germany, Italy, Slovenia and United Kingdom. The project gives an assessment of the acceptance level of consumers based on the findings of the quantitative and qualitative research. The following conditions were found to be important in order to convince consumers to buy smart appliances:

- Technology is considered as mature and experiences are available.
- Acceptable prices and/or subsidies are given.
- Consumers have a financial gain by using smart appliances.
- Feasible cost models are available.
- Users' comfort is maintained or enhanced.
- Good information about smart appliances is available.
- The appliances have a good usability and attractive designs.

Quite many objections were found, like safety of smart appliances, loss of control and additional costs. The consumers' attitude towards the monitoring of their energy consumption was found quite positive [21].

.....

The willingness to change consumer behaviour was analysed on the basis of the interviews [21]. Consumers would accept changes of their user behaviour to a minor degree. In general, consumers had some difficulties to estimate how often e.g. per month they would use the smart operation mode. Consumers do not have any real experiences with smart appliances so far. The use of the SG appliances is on one hand strongly related to individual habits and living conditions (working hours, children in the house, living in flat or house) and on the other hand depends on the respective appliance. A precondition to change consumer's user behaviour is a financial benefit. Similar is the situation with regard for the time interval for postponing the service.

Consumers would be interested to get information about their energy consumption and the price. Some consumers would prefer to get the feedback directly, via display on the device, because then they can react accordingly (e.g. green light flashes up to indicate that renewable energy is available now). Data about energy consumption and use patterns should be saved for a longer time period. The online availability of data would also be interesting for some users. The information of saved money, saved energy and saved CO<sub>2</sub> equivalent seems to interest the consumers. The information should be provided in a simple, easy understandable way [21].

### **3.2.2 Web and ASTEKA inquiries**

Relevant results from the research projects described above, as well as material from the projects EU-Address, ENETE and INCA projects have been used as background material for the web inquiry carried out in this SGEM WP1.2 project. The target of EU-Address is to enable the active demand in the context of the Smart Grids of the future, or in other words, the active participation of small and commercial consumers in power system markets and provision of services to the different power system participants [57]. One task in the ENETE project was to simulate price control methods for electrical heating [58]. The third project is called INCA, INteractive Customer gAteway and its exploitation in managing the electricity system and in the services incenting the energy efficiency [59].

The goal of the web inquiry was to find out the household consumers opinions on opportunities brought to consumers by SG's.

The web inquiry was designed and realized on the basis of cooperation of all the participants of the work package. The questions were drafted mainly by VTT and finalised by the other participants. A webropol tool was used for conducting the inquiry and for the preliminary analysis. The inquiry started in September 2010. Answers obtained until 21.1.2011 were analysed.

The following themes were included in the questionnaire for end users:

- background information of the consumer: living area, education, gender, age, yearly income, family size

- Information of building: house type, building year, size, heating type, plans for changing the heat type
- environmental impact: energy saving
- possibilities for 'own' distributed generation and energy storages: micro generation, electric car
- tariffs, flexible loads and possibility/willingness for controlling the loads
- expectations for smart metering: economic, environmental etc
- data security, integrity
- user interface: controlling system, data available.

In the analysis part of the answers received for the ASTEKA inquiry and web inquiry are compared.

The ASTEKA inquiry was made within the project ASTEKA, which aimed at monitoring the wellbeing and energy efficiency in smart houses. The project concerns indoor air measurement, fine particles and market analysis. ASTEKA service was an outcome of the project. The service was piloted in eleven buildings on House Fair in Kuopio 2010. Among other things the service enables the monitoring of real time consumption of electricity, heat and water. Additionally, the service can produce alarms in exceptional conditions [61].

The ASTEKA inquiry was carried out during the House Fair. A laptop was available for the visitors to answer the questions.

The following themes were included in the questionnaire for the visitors of the House Fair in Kuopio:

- background information of the consumer: address, age, gender, education
- Information of building: house type, building year, heating, energy class of building, air conditioning, filtering of incoming air
- energy efficiency vs. indoor air quality: needs for energy efficiency services
- specific questions about ASTEKA service
- way of getting the feedback
- monitoring of energy efficiency and indoor air quality
- how much the respondents would pay for the service.

### **3.2.3 Analysis of the inquiries**

The total number of answers from the web and ASTEKA inquiries was 500. Answers to similar questions in both inquiries, dealing with consumers' acceptance, were analysed together.

## General information

Figure 9 shows graphs of the background information, such as the postal code, family size and the age of the respondent. The living area was distributed quite evenly for urban, suburban or rural areas. One and two persons' families are dominating, 80 % of all answers in web inquiry. The age was divided quite evenly from 25 to 65 years; the dominating age step was 25-35 years

Other factors like gender and education have quite equally distributed answers. The respondents in both ASTEKA and web inquiries were 47 % women and 53 % men. In the web inquiry the women's share was about one third. The education was quite evenly divided between: comprehensive school, secondary school, vocational high school or university degree. Regarding yearly income the majority (57%) earns between 20 000-50 000 Euros.

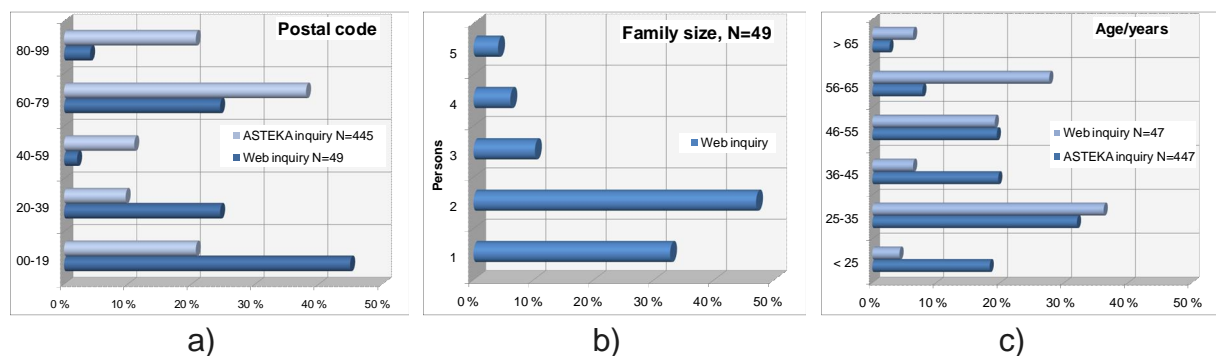


Figure 9 Background information in inquiries: a) postal code, b) family size and c) age of the respondents.

## House types and heating.

The detached house is the most popular type within the respondents of both inquiries; see Figure 10a). In the web inquiry heating types district heating and electric heating are divided evenly. In some single residents also wood, oil or ground heating is used. 55 % of houses use additional heating like wood, heat pump and solar energy. 20 % of respondents already have or have planned an air or ground heat pump. Five households have planned solar heating and two wind power.

In ASTEKA inquiry 42 % of households have district heating and 35 % electric heating. Oil heating, ground heat pump and wood represent close 25 % of the answers without don't know -answers. About 60 % don't have additional heating commonly used as additional heating.

The main heating methods of both inquiries are shown Figure 10b). Quite similar proportions are seen in the inquiries in spite of the big difference in the number of answers. District heating and electric, both direct and storage heating, heating are dominating. The title heat pump in main heating type means ground heating. In additional heating forms heat pumps refer either to ground heating or air heat pumps.

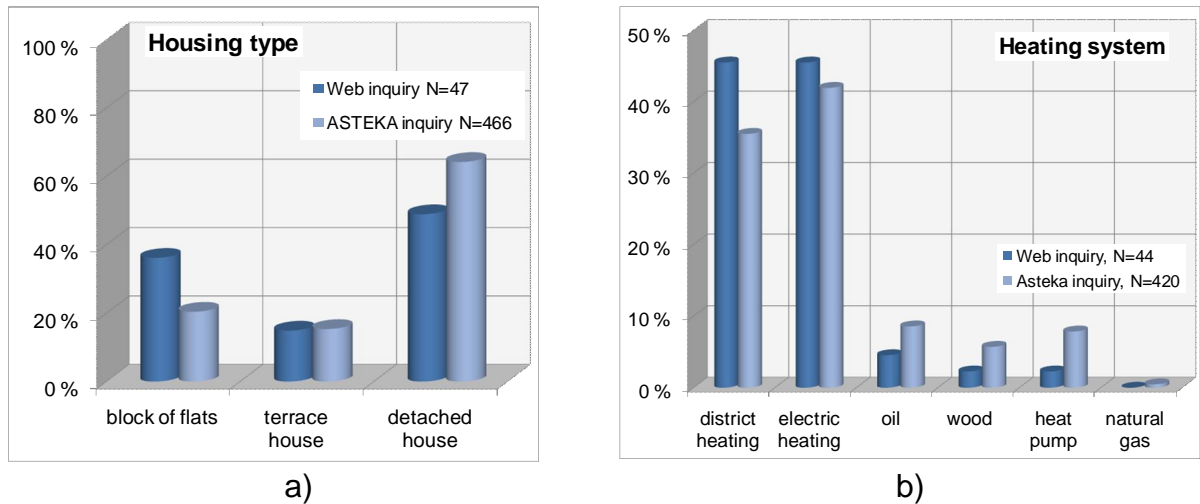


Figure 10 a) Different housing types and b) main heating systems of the households in web and ASTEKA inquiries.

Figure 11 shows the main heating type in different house type and the additional heating type used for the different main heating types.

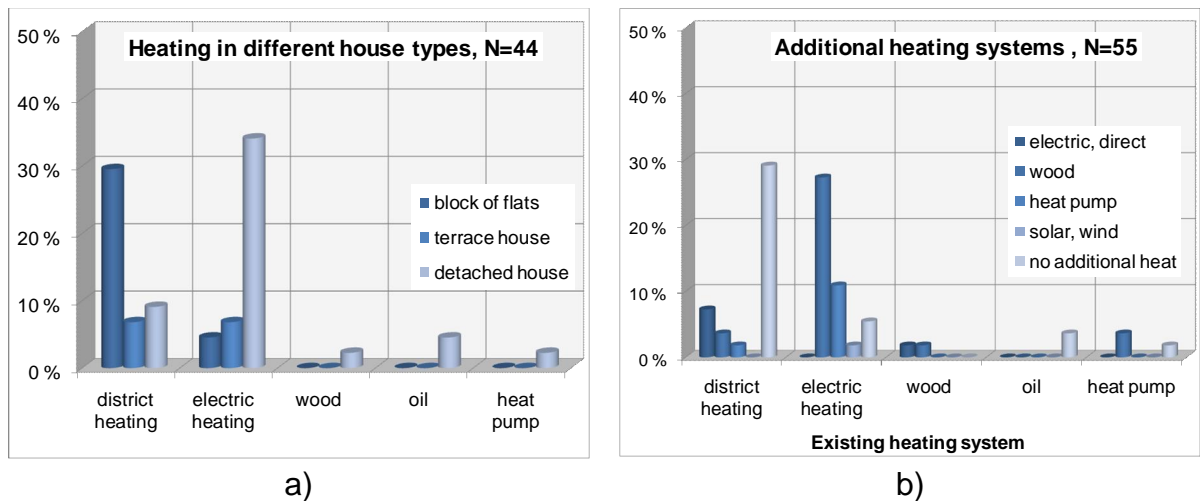


Figure 11 a) Main heating types in different house types and b) additional heating types used in conjunction with the existing heating systems, web inquiry.

It was possible to give additional free form answers to some question groups of the web inquiry. Those regarding the heating systems are presented in Annex 1.

### Environmental aspects

In the web inquiry the readiness for the environmental issues was asked as measures done or planned for reducing greenhouse gases. Figure 12 depicts the answers specified by the housing type. Most respondents have already shortened the operating time of the electrical devices. The respondents also find it possible to change to energy saving devices or reduce the consumption by home automation. Only few respondents found it impossible to realize any of the mentioned measures.

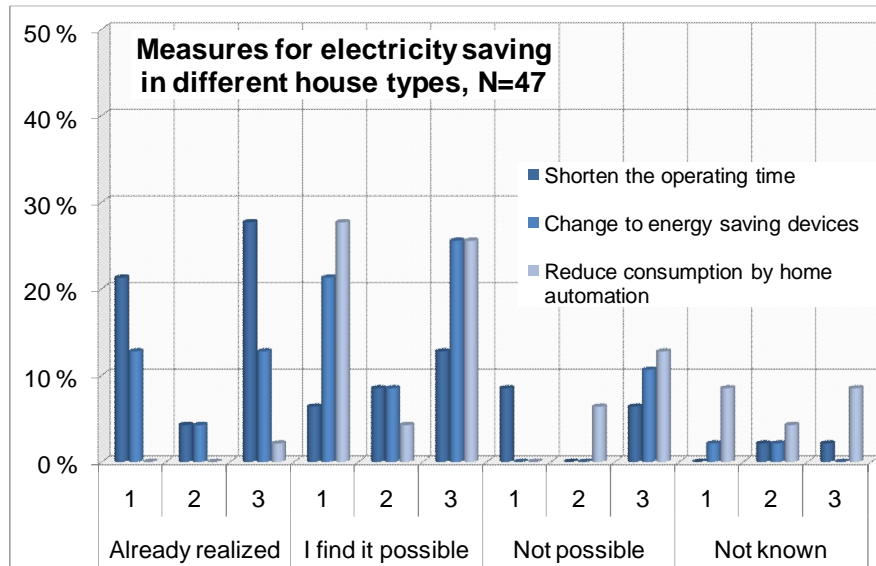


Figure 12 Web inquiry: What measures would you use in order to achieve the target of greenhouse gases? Results are given as percents of the total number of answers. The house type is given as numbers: 1 - Block of flats, 2 - Terrace house and 3 - Detached house

#### *Distributed generation and energy storages*

Majority of the households have no micro generation and only about ten percents have planned to build wind or solar power. 42 % of the respondents would purchase a plug-in electric car. Those who wouldn't had the following reasons: too expensive (43 %), too short range of operation (25 %) insufficient recharging possibilities (18 %) and other reasons (10%). Most frequent other reason was the respondent does not need a car.

The free form answers for the "other" reason for not buying an electric vehicle are presented in Annex 1.

#### *Tariffs and pricing*

The price of the electric energy depending on the consumption and spot-prices would be one element in driving the demand response in practice among household consumers. The question about changing the contract based on the dynamic pricing gave totally 30 % of YES-answers and 70 % of NO-answers. The answers compared by house type, age and living area are shown in Figure 13. No-answers are dominating in all comparison groups. Number of answers was N=49 in these web inquiry comparisons.

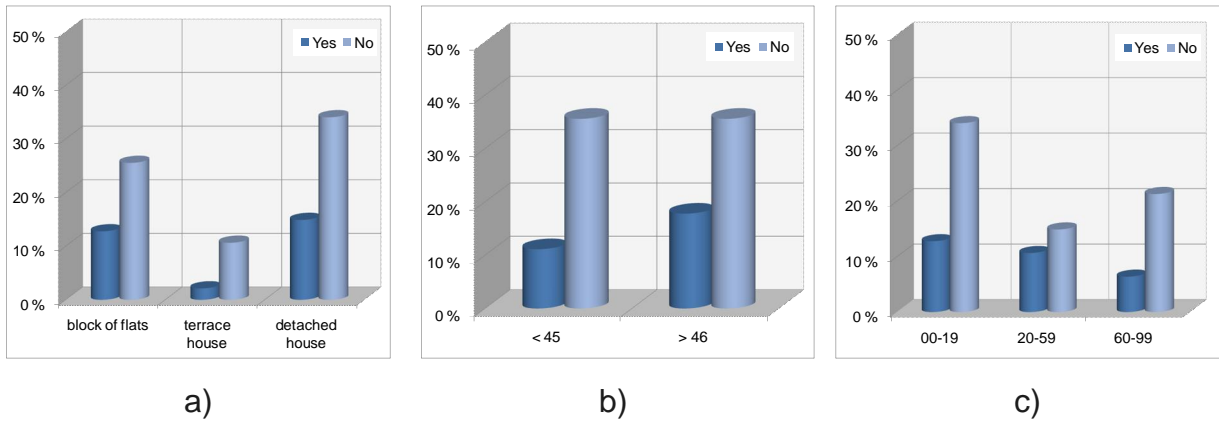


Figure 13 Would you change your contract based on the dynamic pricing? Comparison a) between house types, b) by age and c) area, postal code, Web inquiry, N=49.

### Demand response

Two questions dealt with readiness to demand response possibilities, see Figure 14. Switching off the heating for one hour received quite negative answers: totally 70 % answered only in exceptional cases or never. The number of households having electric heating was 18.

Another question in this group dealt with postponing the start of certain device groups. “I would not allow” is dominating in the answers, but still in some groups the user will allow the postponement, especially if they have a possibility to cancel the postponement. The postponement will help in peak shaving on the general level and reducing the customer’s energy invoice based on the dynamic pricing. So, heating, sauna, washing appliances and lighting belong to those that could be used as shiftable loads in the demand response concept. The respondents regarded cold appliances most problematic. See more details in Figure 14b). The question was formulated: would you allow the electricity company to postpone the starting of the home appliances later? Controlling of cold appliances will be restricted so that no spoilage is caused to food. For special cases like deep-freezing large amount of food, the user can control the appliance.

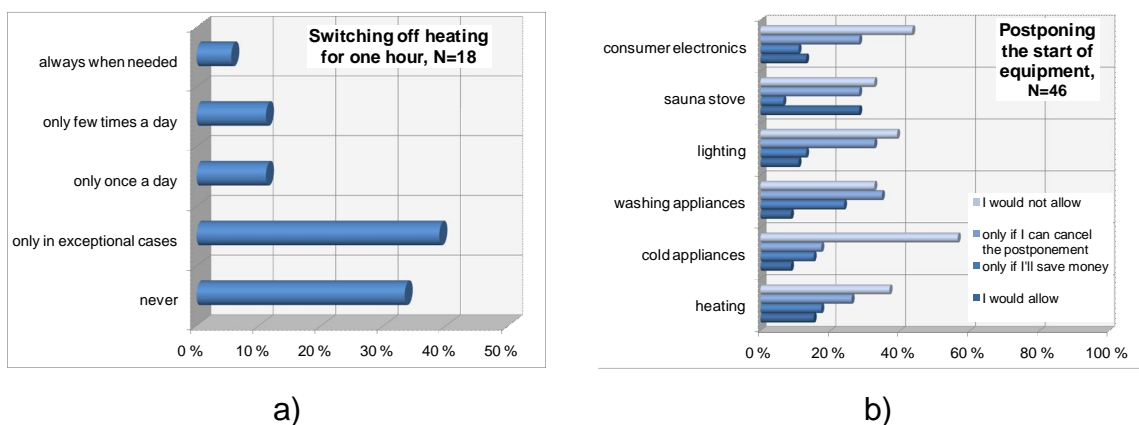


Figure 14 Readiness for demand response a) in heating or b) postponing the start of the other loads.



Interface

Questions about interface were asked in both web and ASTEKA inquiries. The answers on “how and how often” from web inquiry are shown in Figure 15.

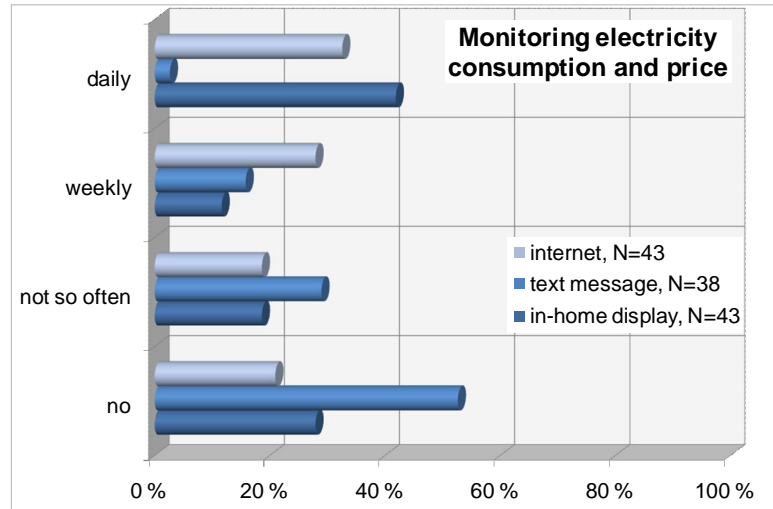


Figure 15 Means of monitoring of the electricity consumption.

In the web inquiry both internet and in-home displays are quite equal for the monitoring device. Most respondents would follow the consumption daily.

In the ASTEKA inquiry totally 85 % of the respondents will be ready to utilize services by internet, mobile phone or a separate display. The most important services were monitoring the consumption and indoor air (53 %) as well as using the control systems (43 %). Other interesting services are building’s maintenance manual, security services and maintaining the drawings. About 40 % of the respondents are interested in three or more services. Up to 52 % of the respondents considered the ASTEKA as an interesting and illustrative service.

Figure 16 shows the willingness of the household respondents to be able to monitor in detail their consumption. Almost 90 % agree with this possibility.

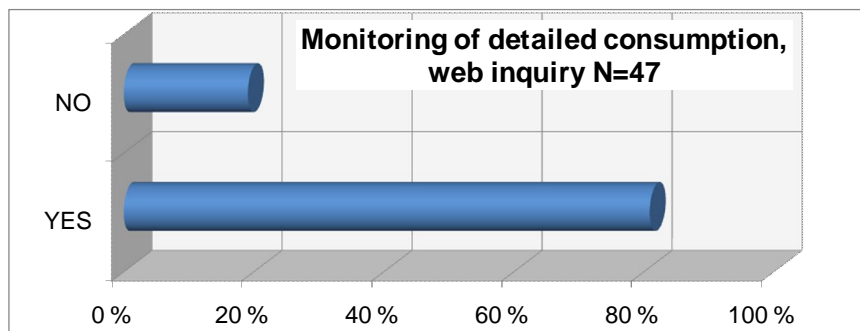


Figure 16 Would you be prepared to give your electricity consumption data if you will get in exchange the possibility to monitor your consumption in more detail, which would make the energy saving controls possible.

Figure 17 summarizes the desired monitoring services of both ASTEKA and web inquiries.

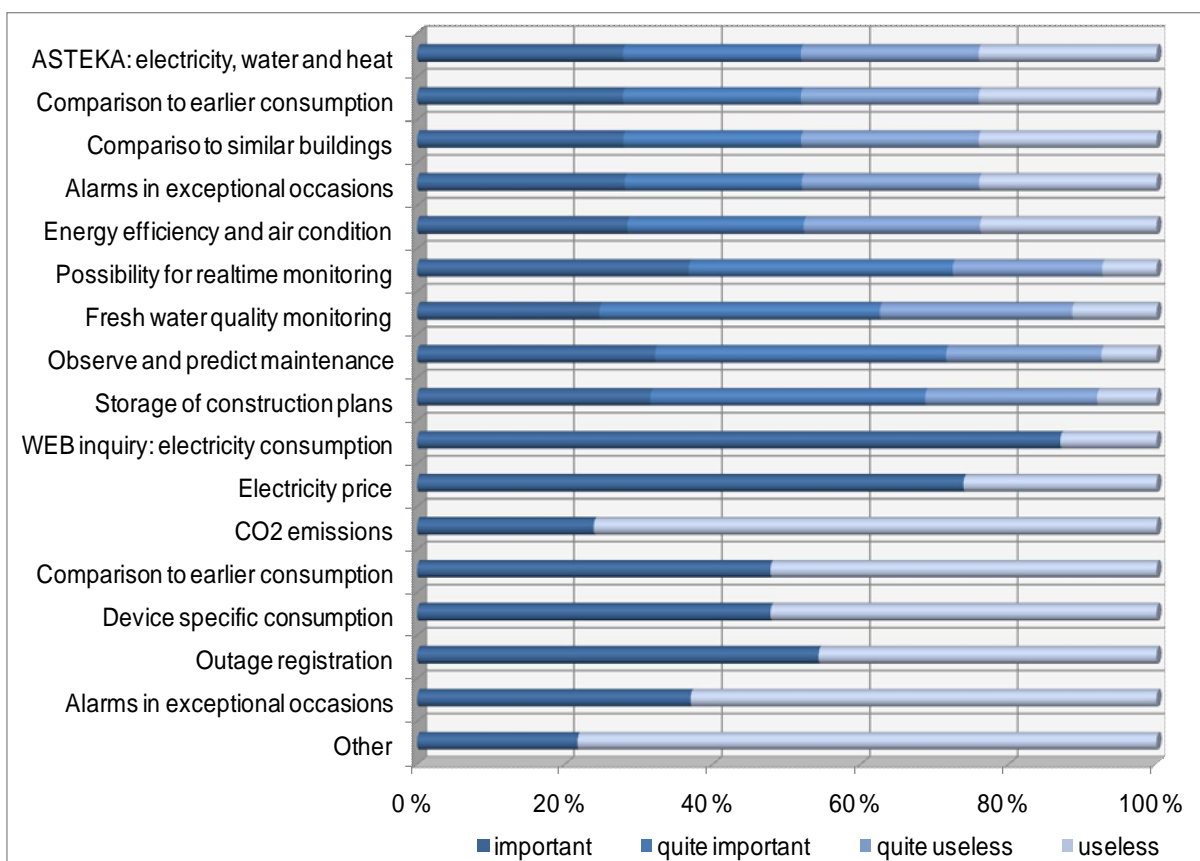


Figure 17 Important services to be monitored by consumer interface in ASTEKA inquiry (N=447) upper part and web inquiry (N=49) lower part of the list.

Most respondents of web inquiry were not willing to pay for the consumer feedback services or devices based on information enabled by Smart Grids. The answers distributed as follows: nothing 76 %, less than 20 €/year 16 % and 20-50 €/year 8 %. ASTEKA service will provide more information about the building. In ASTEKE inquiry the answers were: nothing 33 %, 10- 20 €/year 31 % 20-50 €/year 8 % and 1 % more than 100 €/year.

The free form answers concerning consumer interfaces are shown in Annex 1.

#### *Remote controlling, data security and privacy protection*

Free comments were asked for the following questions about possible dangers or disadvantages caused by the control as well as about data security or losing the privacy protection. The presented points of view concerned the following issues:

- *danger in remote control:* The user may think that a certain device is not on though it is controlled by an automation system. Unexpected later start might cause a danger. Thus only switching off could be automated and switching on could be done only by the user. Some respondents already have a contract including the possibility of switching of the loads.

- *disadvantages*: controlling both electric heating and cold appliances was found annoying. The cold appliances will first be switched off and food will be left there and go bad.
- *data security*: It is possible that someone who has access to my consumption data will inform criminals: home or not home. Quite many are not afraid.

The detailed comments are presented in Annex 1.

### **3.2.4 Summary of the inquiry results**

The web and ASTEKA inquiries had quite wide and even distribution in their background. The total number of answers was quite low in the web inquiry.

The answers show that heating is very important for the consumer. The additional heating is in use in parallel with the main heating and changing the main heating system has been planned in several cases. Heat pumps were not as popular in this inquiry as the commercial sales volumes would suggest.

In quite many answers the energy saving measures listed in the inquiry have been already realized or the respondents found these measures possible to carry out.

Distributed generation or plug-in electric cars are not yet common in these cases.

The majority of the respondents were not willing to change their contract to one based on the dynamic pricing. Controlling the loads was not commonly found desirable. Still there are some groups of appliances that could be controlled freely or with a possibility to cancel the remote control.

Questions about smart metering and user interface got quite many answers showing a common interest towards them. Consumption and price of electricity are the most important quantities to be followed. The customers are willing to monitor their consumption in more detail, which would make the energy saving control possible.

Free form answers concerning safety in remote controlling, data security and privacy protection brought out different kinds of concerns. The major concerns related to switching off the heating or cold appliances. For instance some respondents found switching off the freezer not desirable. In practice, if the controlling is needed it will be performed such that the food will not perish. Some doubts were presented on the privacy and data security such as the real time consumption data could find its way to criminals. Still, quite many respondents did not feel that there are problems with the data security.

## 4 Considering communication on Smart Grid to consumers

### 4.1 Introducing Smart Grid as a new innovation

A well known concern when introducing new technology to the market is naturally if and how the public will accept it and hopefully makes it a part of their lives. Different innovations take different time before they are accepted in society and sometimes this can be a difficult process, even when the innovation has obvious advantages compared to prior systems. Some innovations spread fast over a wide area, while others take a longer time to get accepted, at all. This is a struggle to most companies and authorities when introducing new ideas, products or procedures to the market, Lindstedt and Mårdsjö Blume and Elforsk report 08:76, [45].

When a new innovation is introduced it does not matter if it really is new, what matters is how people experience it. The opportunities and functionalities provided by smart grid and smart house technology is a new innovation waiting to be introduced to and accepted by the public. The technology is not all new and ideas like saving energy, home automation and producing one's own electricity have been present for a long time. But selling energy back to the grid, interactive user-interfaces and giving outside parties or/and automation systems access to controlling home appliances are new functionalities to the public. One of the big questions is how to communicate all of this to all parties in the system in order to make it spread over a wide area, in appropriate speed.

#### 4.1.1 Rogers' model: Diffusion of innovations

Rogers' model for diffusion of innovations (Rogers, 2003) [46] describes how an innovation is spread through different channels and finally is fully accepted and becomes a natural part of end-users lives. Rogers use the word 'adopt' to describe what happens when people accept an innovation. The four main elements of the diffusion of an innovation are the innovation, communication and the communication channels, time and the social system.

##### *The innovation*

Rogers explains that "*an innovation is an idea, a practice, or object that is perceived as new by an individual or other unit of adoption*". Whether the idea is objectively, actually new, in scale of time since it actually was invented or introduced doesn't really matter. What determines this is the individuals' reaction towards it. If the idea seems new to the individual, it is an innovation. A new innovation does not have to involve new technology or be new to the rest of the world. Some may have known of an innovation but just haven't created either a positive or a negative attitude towards it, nor have adopted or rejected it. Rogers

explains that "*newness in an innovation may be expressed in terms of knowledge, persuasion, or a decision to adopt*".

Rogers has mainly analyzed technological innovations and mentions the accustomed habit of using the word innovation as synonym to technology. Technology almost always consists of a mixture of hardware and software. A technological innovation usually has some degree of benefit to its potential adopters. But this advantage is not always that clear to the adopters who are not always that certain that the innovation represent a superior alternative to the practice it replaces.

Innovations have different characteristics that directly influence the depth of their adoption in society and how long time it take. These can be divided into the five following categories.

- **Relative advantages.** An innovation is seen as an improvement of previous method used. The grade of improvement is seen through the end-users eyes and the advantages can sometimes be measured in economical terms. But social prestige, comfort and satisfaction are also important factors. Better advantages give faster adoption.
- **Compatibility.** Handles how well an innovation agrees with existing societal values, and potential end-user previous experiences and needs. An innovation that crashes with the society's norms and valuations will not be accepted as deeply and fast as on that agrees.
- **Complexity.** This refers to if the innovation is seen as difficult to understand and use. New ideas which are easy to understand and use are more easily adopted than innovations which demand personal involvement and development in knowledge and understanding. This has little to do with whether the technology behind the innovation is complex or not, but how the user experiences it.
- **Trialability.** Is it possible for the end-user to at least to some extent experiment and play with the innovation? The easier it is and the faster the end-user can test at least some part of the innovation the faster it will be adopted. This lowers end-user insecurity and shows that learning-by-doing is a possibility with this product. That lowers the complexity level.
- **Observability.** This handles to what extent the innovation is visible to the end-user and other individuals. The faster the end-user can see the results from the innovation, the more likely it is to be adopted. Visibility also triggers conversation between individuals which contributes to spreading the innovation, Rogers 2003 [46].

### *Time*

Different kinds of people have different interest in and ability to adopt innovations. The diffusion of innovation process explains the process in society

of accepting and adopting an innovation. The process includes the time it takes from the moment when an individual first hears of the innovation, to form an opinion of it, take the decision whether to accept or dismiss the innovation, implement the new idea and finally confirms the decision. In this process people are divided into five categories:

- Innovators. People who actively search for information and new ideas. These people need economical assets and the ability to understand and implement complex technical knowledge. These people have the ability to handle uncertainty and are seen as gate keepers in the flow of innovations. This is a rather small group of people and consists only of 2.5 % of the big mass.
- Early adopters. This group of people is better integrated in the society than innovators. They act as creators of public opinion since they are seen as intellectual people in the society. These are the role models in society and consist of a larger group of people than the innovators, 13.5 %. This is the group of people companies usually aim at for recognition since innovations approved by this group is generally also approved in the society.
- Early majority. This group of people picks up innovations just prior to an average person. This group is also considered important since it is rather large, 34 %. This group is together with early adopters considered to be the critical mass when innovations are introduced.
- Late majority. The people in this group are skeptical towards innovations and pick up on them right after average people. This group of people also makes out 34 % of the big mass.
- Laggards. The last group of people to pick up on innovations. The people in this group are traditional and like the way things used to be before. These people often have a limited economical situation and have to be extremely cautious on what they buy, Rogers [46].

The distribution of the groups is shown in Figure 18. From the figure can be read that the early adopters and early majority are referred to as the critical mass. When an innovation has been adopted by these groups it is considered to have gained enough support from the society to eventually become fully accepted. That is why innovations often are communicate din a way that makes them interesting to and understood by people in those two categories

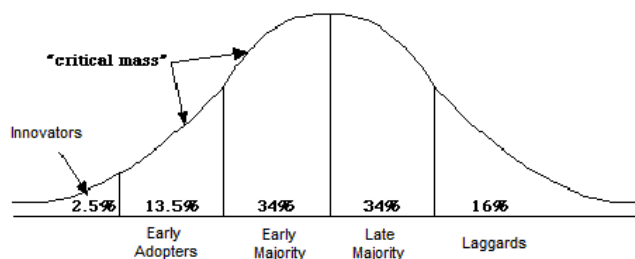


Figure 18 The bell curve different social groups [45].

### *Communication channels*

Messages flow from one individual to another through communication channels. Mass media communication channels are very effective in spreading knowledge. Interpersonal channels are even more effective in forming or changing attitudes towards new ideas which, influences the decision whether to adopt or reject an idea. Most individuals do not base their decision of adopting innovations on scientific research but on stated opinions of near peers who have adopted the innovation. Rogers also mentions that new media affects communication in a positive way.

### *Social system*

All of this takes place in a social system, consisting of a group of people with a joint problem solving in order to accomplish a common goal. The system has structure, a pattern of arrangements of the people in the group, which gives stability and regularity to individual behaviour in a system. The social and communication structure of a system decides the diffusion of an innovation within the system. One example of a social structure is norms, which establishes patterns of behaviour within the group. Opinion leadership is the degree of which an individual is able of affecting other individuals' opinions of an innovation in a desired way.

#### **4.1.2 Reflections on smart grid solutions in the light of Rogers' model**

All the factors described above should be taken into account when communicating smart grid and smart house innovations to end-users. The categories described by Rogers' model and the categorisation of people can be used to model the smart grid solution and how it is presented to the public. Different people respond to different criteria.

In their report Lindstedt and Mårdsjö Blume discuss the new AMM meters and how the introduction of AMM meters relates to the diffusion model [45]. According to them, the AMM meters are in most cases hidden, they are not visible to the end-user. They are not intended to be experimented with and what most of the end-users really get from this system it is a precise electricity bill every month. Consequently, that makes them compatible with the previous system and precise bills are seen as an advantage. Even if some criteria are not fulfilled the two of most importance are. This means that they most probably will be accepted by the social system. However, fulfilling more criteria would speed up the diffusion process.

Depending on how the technology is used, different functionalities can be achieved and at the same time, according to the diffusion model, the characteristics of the innovation, experienced by the end-users, is changed. The AMM meter can be included in a larger system introducing further developed functionalities which changes it into another innovation. However, when adding

further functionality and perhaps complicated functionality, the complexity level also raises. This demands for a higher level of involvement from the end-user and limits the diffusion.

To sum this up, when smart grid and smart house technology is communicated it should replace a previous lacking system or give some kind of additional advantage which could be economical or provide comfort or be satisfactory in some other way. It should be compatible with social norms and valuations. Different components and functionalities could be used to bring forth appropriate characteristics of the innovation within different levels of the smart grid and smart house solutions.

Interactive user interfaces can be used to increase the observability and trailability. Mobile units would also increase these characteristics. However, when developing the functionality of the user interfaces it must be considered that they should also match the model. Interactive functions and customer interaction through the user interface can add to the real advantage characteristics since interaction with service providers is simplified.

Energy storages at end-user's premises and DG units also add to the visibility category. They can be shown to others and DG units seen from the outside inform others that the owner has adopted the innovation. Consequently, information concerning produced, and sold, electricity can be displayed on a graphical user-interface to raise the observability level and add to the trailability level when the end-user is able to experiment with different layouts and time scales.

Displaying energy consumption on device level adds to the observability level and the trailability level. This can also raise the 'real advantage' since the amount of electricity consumed can be seen per appliance or as a total of a group of appliances. This allows the end-user to actually see how much electricity is consumed per appliance or group of appliances, per activity, and the end-user can decide based on that how much is considered acceptable to pay per activity.

Load control is a functionality that could collide with the compatibility characteristic. Allowing outside actors to control in-house appliances might not be considered desirable. In this matter it is essential how the service is modeled and described to end-users. Disconnecting loads at critical situations would be a real advantage in shortened service time. Development of a commercial DR functionality would allow end-users to operate their appliances in an economical manner and avoid extensive grid expansion. This service could be grouped with other end-user services in order to create a package of end-user services.

## **4.2 Provision of information to consumers**

The role of provision of information to the consumers is fundamental within the Smart Grid concept. The way the consumers perceive and comprehend issues



concerning Smart Grid technology influences their trust on and acceptance of the system. There are also other important factors that affect the acceptability, especially social issues, but they are not handled here.

In this chapter, the focus is on the quality of the provided information. The way of choosing and presenting the information within the Smart Grid context affects the consumers' actual possibilities of comprehending issues that are necessary for gaining an understanding of the Smart Grid concept and for being able to use and benefit the technology.

In the following, examples of instances manifesting lack of knowledge or understanding among the consumers, concerning, on one hand, use of energy and energy efficiency and, on the other hand, the Smart Grid concept, are presented. These instances are described with the help of extracts from selected literature (e.g., relevant research projects and articles). After that, points of view on implications on the development of Smart Grid concept and technology are discussed.

#### **4.2.1 Examples of consumers' lack of knowledge or understanding**

The references of the extracts to be presented here are given in the end of the last sentence of each extract. Some minor modifications have been made on the expressions, in the form of shortenings and omissions.

##### **4.2.1.1 Information on use of energy and energy efficiency**

Domestic energy consumption is still largely invisible to millions of users and this is a prime cause of must wastage. Most people have only a vague idea of how much energy they are using for different purposes and what sort of difference they could make by changing day-to-day behaviour of investing in efficiency measures. Feedback on use of energy is, therefore, important for making energy more visible and more amenable to understanding and control [22].

Feedback is not always sufficient – sometimes people need help in interpreting their feedback and in deciding what courses of action to take – but without feedback it is impossible to learn effectively [22].

Energy means different things to different people. Studies have found that people do not know much about how and where energy is used. While such findings suggest that more public education is necessary, they can also be criticized for exhibiting a "deficit model" of lay knowledge concerning energy. It is assumed that because lay people do not have the same kind of knowledge as experts do, they know nothing. ---- Experts simply frame energy use in different terms – often ones that are distant from ordinary households' or organisations' needs and concerns. They fail to understand why households behave "irrationally" because they fail to grasp the logic of energy use. The exchange of energy efficiency knowledge among experts and lay people reflects a fundamental problem in product innovations. ---- This problem slows down the uptake of innovative

solutions – many rounds of information exchange are needed in order to establish facts and clarify perspectives [54].

Consumers seem to be both unaware of the amount of energy they use and are swamped by information about saving energy. They feel that they are bombarded with information and advice on carbon emissions and environmental pollution but have still very little knowledge about what solutions there are to the problem [55].

The advices that people hear and can act on needs to be improved; vague exhortations to reduce one's carbon footprint are not very actionable. It seems that the problem is that, while there are lots of organisations talking about energy saving, knowing who to trust and how to act is very difficult [55].

Too much information is as likely to lead to consumer apathy as too little in terms of actually changing behaviour rather than just expressing concern. With so many messages, consumers will have to become better editors of information regarding energy efficiency and rely on word of mouth for advice. The explosion of coverage of carbon footprint issues in the last few years has left many consumers confused, leading to agreement with the expression "I am concerned about what I personally can do to help protect the environment" [55].

The crucial issue is how to translate the recognition of personal responsibility for the issue into a greater degree of action. People feel so overloaded by ethical pressure that they don't know where to start in changing their [55].

#### 4.2.1.2 Information on the Smart Grid concept

Most consumers have difficulties in understanding the underlying concept of smart operation [21].

Regarding automatic regulation some consumers had difficulties to grasp the concept. They also had doubts that the technology is working safely and whether this solution is really energy-efficient [21].

The more the systems work automatically, the higher the comfort for the users, but at the same time automation is rejected because users feel uncomfortable with it [21].

The major concern of consumers is that they feel uneasy to leave their appliances switched on, if they are not at home or during night. The perception of risk depends to a very high degree on their current use of practices and their knowledge about the technology. Even if they would get the guarantee that from the technological point of view there is no risk they feel uncomfortable about it – mostly because they do not understand how the appliance is working [21].

The second major concern for consumers is an anticipated loss of control. One background reason of this feeling is certain mistrust in high tech solutions [21].

.....

There are many objections which have to be solved before a market penetration of smart appliances is feasible. These objections can be summarised as follows:

- Doubts about the safety of smart appliances
- Doubts whether technology is mature
- Fear to lose control
- Concerns about additional (hidden) costs
- Doubts that ecological effects will be met
- Scepticism about motivation of main actors. [21].....

There is a lot of consumer scepticism that economic goals are hidden behind a "green washing" attitude. As consumers pointed out, information provided by the main beneficiaries (energy suppliers, manufacturers) will be met with reluctance [21].

Ecological benefits of smart appliances are not communicated to the consumer and seen as being only used as sales arguments. The behaviour of consumers might be not smart even if they have smart options within their device. [56].....

Consumers are not being informed about already available intelligent technological possibilities like start time delay function, absorber technology or inverter technology and their benefits. [56].....

One of the factors that potentially hinder the success of smart domestic appliances is discrimination of certain user groups (e.g. elderly people) who might be overstrained by new and smart technology. It is unsure how much information has to be distributed with the appliance: people might misunderstand the function of the smart appliances [56].

The interviewed consumers had a vague notion that the meters would be changed and very few knew why. In addition, nobody really understood the concept 1 kWh and what this meant in terms of electricity consumption. The respondents also said that as they were unable to calculate how much energy an apparatus used, they had difficulties in determining whether it was worth changing to an energy-saving alternative or not. It was also evident that the respondents both admitted their ignorance and distanced themselves from the matter. They also maintained that everyone knows that electricity bills are incomprehensible and that complaining about them is natural. [45].....

The interviews clearly showed that when it comes to energy, all the respondents have a low degree of subject-involvement. They know very little about the physical measure 1 kWh, energy consumption, and experience that they "fall short" when it comes to energy matters. They will also find it difficult to link their total energy consumption with different types of apparatus in the future, because they are unable to apportion their consumption. Even with the new monthly

readings, the consumer will still have a lot to work out, interpret and understand. [45]

It was also clear that the respondents had a relatively low degree of decision-involvement. For example, decisions about the purchase of new household appliances and TV's are often based on parameters other than energy consumption, such as appearance and performance [45].

#### **4.2.2 Implications on development of the Smart Grid concept**

The examples concerning the consumers' lack of knowledge and understanding, presented above, bring out needs of information, the identification and definition of which is not always straightforward. There is need of information that would contribute to reducing the experienced complexity of the Smart Grid system, enhancing trust on the concept and technology and facilitating the use of the system. In addition to the customary information needs, there is, depending on the specific circumstances and situation and the type of the consumer, need of, e.g., contextual and background information and information that makes it possible to understand bigger wholes, causal relationships and influences and also uncertainties and risks.

According to Mert et al., 2008 [21], consumers need to understand the underlying concept of smart operations. Since most consumers have difficulties in understanding the underlying concept of smart operation, good information about the functioning of the electricity grid and the feeding-in of renewable energy is required, which should be provided by the energy utilities. Consumers need to understand the bigger picture and the concrete implications of using smart appliances, to be motivated to adopt them. Also the tariff structure combined with smart appliances has to be easily understandable. The information should help the consumer to get an idea of his load curve, his saving potential and what are appropriate actions, such as peak load reduction.

With energy production (microgeneration) as with consumption, it is important to make the whole process as visible as possible [22].

Consumers need relevant information about the background of the system to ensure their cooperation [22]. The background information may concern, e.g., the way the price of the energy is formed, the goals, structure and participants of the system and the way the benefits are divided among the participants. For part of the consumers knowledge of what is happening on the grid could be interesting and useful [22].

Taking account of the consumers' information needs poses challenges to the development of the Smart Grid concept and to the electricity and energy companies.

Adoption of a contextual approach provides means for taking better account of the consumer in the development of the provision of information. The quality of

afforded information can be increased 1) by, firstly, identifying the consumers' demands for understanding, concerning both the Smart Grid concept and the use of energy with the help of Smart Grid technology, and, 2) after that, by identifying the information needed to fulfil these requirements.

The contextual consideration of the consumers' needs of information requires systematic cross-disciplinary collaboration of experts from relevant fields, including human sciences, and representatives of different consumer groups. Development of use case descriptions for taking a closer look at the consumers' demands for understanding and for defining the consequent information needs would contribute to provision of information that can reduce the consumers' lack of knowledge and understanding.

The energy companies and other operators could pay a special attention to the way of communicating on Smart Grid technology to the consumers. The abilities and final needs for the adoption of the Smart Grid system of an individual consumer differ from those of the other parties participating the system.

According to Lindstedt and Mårdsjö Blume, 2008 [45], the energy companies face considerable challenges when it comes to addressing the different levels of consumer understanding. Making up one's mind about products and the energy consumption also means understanding the unit of measure and what it is that consumes energy. Failure to understand this also leads to difficulties in changing one's consumption patterns, in that no connection is made between the unit of measurement, behaviour patterns and the apparatus used. This naturally leads to complications in the communication context. In communicating with the consumer, this needs to be both understood and taken account of. In order to improve and increase customer interest and their desire to get involved in energy issues, the companies really need to focus on the customer and look at the issues from their perspective.

In addition, there needs to be a common language in which the information is expressed [22]. This, however, poses another challenge, since the complexity of the Smart Grid concept and technology, manifested in the consumers' difficulties in understanding, also reflects lack of knowledge and uncertainty on the characteristics, functioning and entirety of the Smart Grid concept experienced in the electricity and energy companies [64].

## 5 Society view on adoption of Smart Grid

### 5.1 Legislation and regulation for promoting energy efficiency

The national and European regulations are mainly derived from global goals for the climate change mitigation. Certain general goals for infrastructures can locally be set like self-sufficiency, ecological efficiency, safety and healthiness.

One of the most impressive targets approved by EU is the Climate and energy packet, which include binding goals of reducing greenhouse emissions or primary energy by 20 % compared to the level in 1990 and increasing RES energy by 20 % until 2020. These measures promote the third EU target i.e. improving the energy efficiency by 20 % until 2020. Achieving this goal means working to mobilise public opinion, decision-makers and market operators and to set minimum energy efficiency standards and rules on labelling for products, services and infrastructure [51].

Taxes are another regulative action taken into use in several European countries. Increasing total price of the electricity is supposed to lead into reduction of the energy consumption. Finnish Energy Industries has studied the energy taxation in general and especially the electricity consumption taxes in 28 European countries, Japan and USA [48]. The electricity consumption taxes for households are shown in Figure 19. Figure 20 shows the energy tax and the value added tax proportional to yearly consumption on different countries. In Finland the taxes are included in the transmission fee.

The act about electric energy generation using renewable energy sources (RES) has in Finland been given in the end of 2010. The act regulates the support paid from public funds for wind power, bio gas, wood fuel and hydro power, with certain rejections [49]. The support form is called feed-in tariff. Motiva has published a leaflet on Finland Energy Efficiency Agreements 2008-2016 [50]. It covers the energy-intensive sector with emission trading, medium-sized energy users (industry and private sector) and energy services (electricity transmission and distribution and retail; district heating and cooling). The municipal sector agreement includes the Energy efficiency agreement for large units and an energy programme for small municipalities. For oil sector the agreement includes distribution of liquid heating and transport fuels as well as oil-heated properties.

Directive 2006/32/EC on energy end-use efficiency and energy services states a national indicative energy savings target as 9 % of the annual average amount of consumption during nine years, 2008-2016. The saving shall be reached by way of energy services and other energy efficiency improvement measures by end users excluding navigation, air traffic and the industry that is following the rules of emission trade [52].

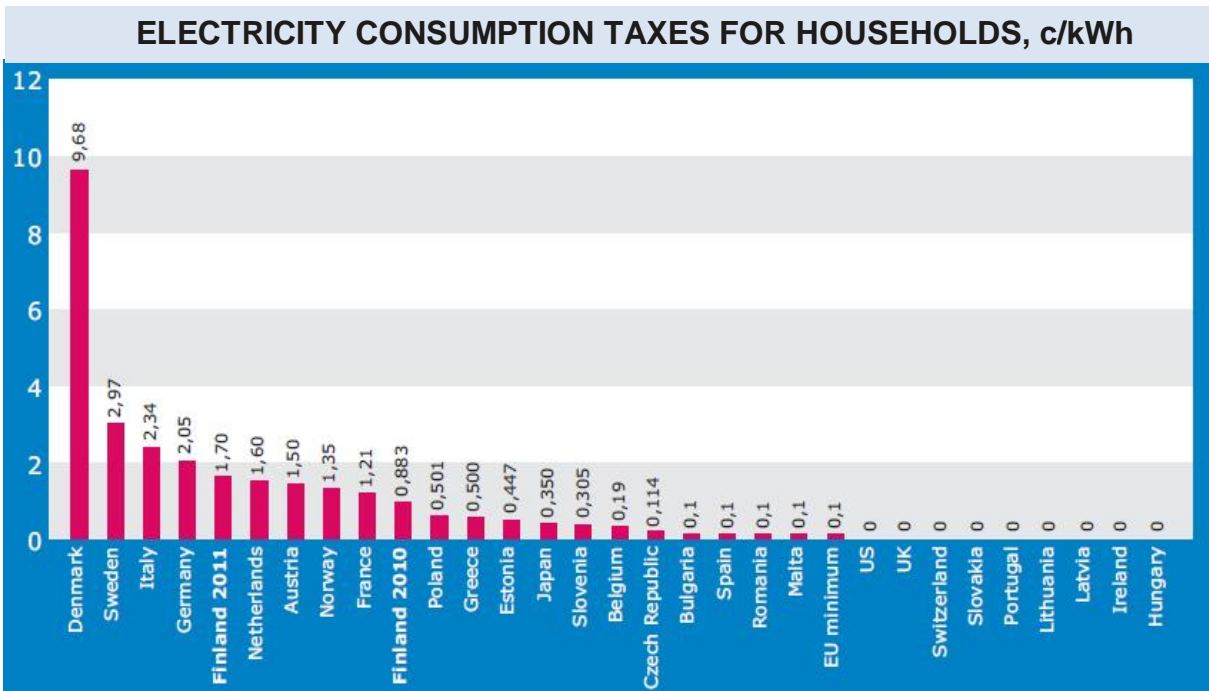


Figure 19 Electricity consumption taxes in 28 European countries, Japan and USA [48].

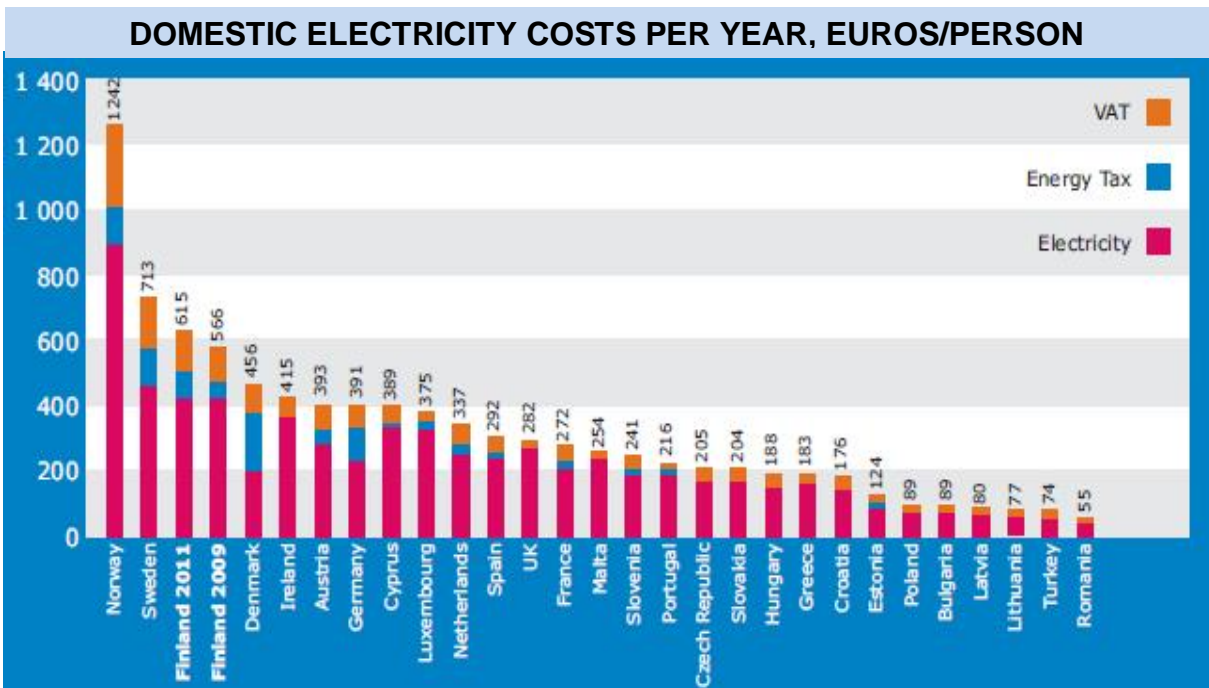


Figure 20 Yearly electricity cost [48]. NOTE: Domestic electricity usage varies considerably in different countries due to seasonal differences in particular, as well as the composition of energy use. The combined burden of electricity price and taxes should therefore be compared also as an annual total cost to households, when assessing e.g. the effect of taxation on purchasing power or inflatory development.

The adoption of automated measuring systems until the end of 2013 is originally based on EU regulations, see chapter 2.4. The main goal in such wide operation is the possibility of saving energy. It has been estimated that the total

consumption can be reduced 0-10 % by getting delayed information of the consumed energy. The instant feedback, less than 10 minutes, has resulted in 5-15 % energy savings during experiments [36]. The schedule of changing the meters, the measuring and reading intervals vary from country to country. In the European countries the measuring interval can be from one minute to one month. In Finland the hourly readings are recommended to be recorded daily, in other countries the interval varies from one hour to one month [38].

The citizens' awareness of the climate change has increased and the climate change mitigation has reached an important position in the Finnish society and widely in the world. Energy efficient solutions and those reducing the green gas emissions are mostly based on electric energy which, however, increases the electricity demand. Some examples are moving from oil heating to geothermal heating and in the future the electric vehicles. Energy efficiency is propagating, but it is not clear when the new technologies will be commercialised [47].

Recognising the focus group in energy efficiency campaigns will be more important than ever. The electricity use is fragmented and many single devices with high consumption will not be significant in the average value of the whole country. One potential device group is the old cold appliances. Positive progress in energy efficiency area has been going on with some devices, partly due to the energy marking. The practises of the use have also been changed, which is seen especially in shortening the operation time [37].

## 5.2 Forecasts on energy demand in Finland

Finnish Energy Industries presents the forecast for the electricity demand in Finland until the year 2030. The estimation is based on a vision of the welfare and prosperous society. The starting point in different sectors has been assumed to follow that vision: the population will grow about 10 % until 2030; in the economy the national product is estimated to grow 2 %; the industry will recover and the importance of services will increase; energy efficiency is supposed to improve in all sectors, for instance with tightening the requirements in buildings; the climate change has supposed to decrease heating but increase cooling needs [47].

In the report Electricity use in households [37] the saving potential in electric energy use is estimated for years 2015 and 2020. Figure 21 shows the yearly saving potentials for different appliance groups. The highest saving potentials are in lighting and cold appliances. The potentials are considered technically, not economically. The electric energy saving potential is around 2.5 TWh using the energy efficient devices. The total yearly energy consumption in households excluding the electric heating is of order 11 TWh in 2020, supposing that Business-as-usual devices are used. The total yearly energy consumption in electric heating is of order 12 TWh in 2030 including the consumption of the cooling and heat pumps. [37] [47].



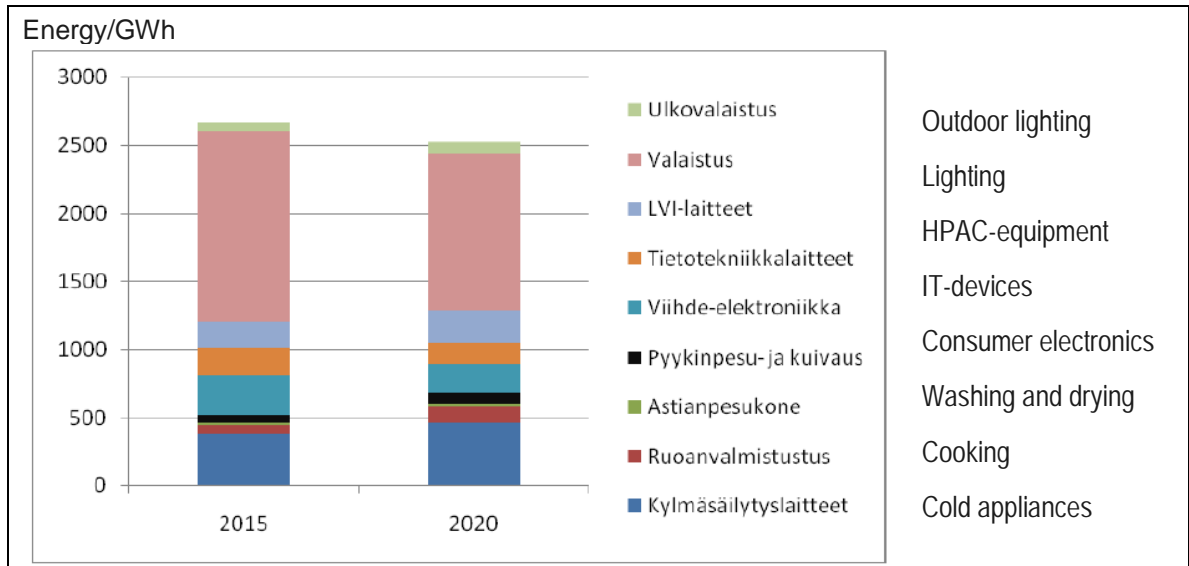


Figure 21 Energy saving potentials in electric appliances excluding the heating [37]

The changes in transport has been estimated such as with the plug-in cars will be driven about 19 % and the electric vehicles (EV) 7% of thy early vehicle kilometres in 2030. Figure 22 shows the estimated development of the new cars during 2000-2020. It is estimated the total electrical energy in transport sector would be 3 TWh.

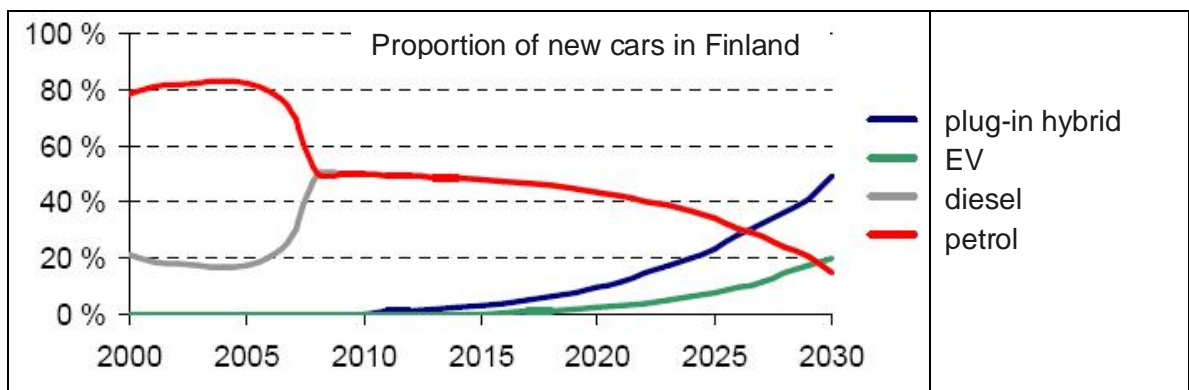


Figure 22 Proportion of different vehicle types [47].

In addition to heat pumps and electric vehicles, new lighting systems have already been invented. The final breakthrough for instance of the led illumination systems are still waiting for coming [37].

The change in age distribution is expected, i.e. the proportion of the retired persons will increase [47]. Aged people often need higher room temperatures and better illumination. It is not supposed that this group is eager to build up the monitoring or control systems.

## **6 Regional modelling of electricity consumer behaviour and the consequent electricity loads**

### **6.1 The benefits of predicting regional electricity consumer behaviour**

Predicting electricity consumer behaviour is important in many ways. In short term, it is necessary to approximate the potential hourly loads so that the power demands can be met without interruptions in the delivery. In long term it is also important to estimate the adoption of new innovations that can significantly affect the patterns and the magnitude of electricity consumption.

As one example, predicting the electricity consumer behaviour helps in planning the grid's future expansion and maintenance appropriately. The grid components are expensive investments and their lifespan can be counted in decades. The better the investments can be planned beforehand, the better return on investment they normally provide. The concept of smart-grid further complicates the strategic planning and, at the same time, makes it even more important.

All in all, being able to estimate at what rate and in what areas the new Smart Grid related innovations are being adopted has a potential not only for securing the uninterrupted delivery of electricity but also for gaining significant financial savings. The benefits are evident for the distribution companies but, as a consequence, the effect is likely to be seen also in the consumer electricity distribution prices.

### **6.2 Regional modelling as a tool for strategic planning of electricity networks**

When making future plans for an electric power delivery network, three basic questions must be answered. What is the amount of energy that needs to be delivered, to which location and when. [1] As a result of increasing investments to renewable energy, growing distributed electricity production and the emergence of technological innovations like electric cars and heat pumps, the task of anticipating the future need of electricity becomes much harder while it also becomes increasingly important. Regional modelling of electricity consumption (also known as spatial electricity load forecasting) attempts to give answers to the questions of how much, where and when is the need for electricity. [1]

There are two basic categories to which most of the used methods for modelling the electricity consumption can be included. In the first category are the trending methods where the load is forecasted by extrapolating the past load profile into the future. The second category includes the simulation methods which attempt to forecast the load by modelling the factors that are affecting the magnitude of the load. [1] While the trending methods are somewhat useful when modelling the electricity use in a large scale, they are not very accurate when the spatial

resolution gets higher. Simulation methods can be more accurate when making longer term forecasts and provide a better understanding of the individual factors affecting the consumption. In practice most of the models are hybrids and combine two or more methods.

The regional electricity consumption can grow because of increasing amount of electricity users or because of increasing magnitude of the existing users' consumption. [1] As such, when predicting the future loads regionally, information is needed for the new use sites and for the changes of the behaviour or the consumption habits among the existing users.

### **6.2.1 Current state of the long term electric load forecasting**

Over the years, multitudes of methods have been used for predicting regional electricity load. Nowadays computationally intelligent methods are exceedingly common and used in various ways. These include artificial neural networks, fuzzy logic and evolutionary algorithms among others. More information about the different methods is provided in several papers. [2][5][6]...

The various predictions and forecasts each cover specific temporal and spatial scale i.e. short, medium or long term forecasts on neighbourhood, municipal or national scale. In strategic planning of the grid, the estimation of the future needs must be made on long term. This can mean predictions spanning from 1 to even 30 years ahead. Most of the models however, are developed for short or medium term forecasts which serve better daily or weekly management decisions. [2] Intuitively a conclusion can be drawn that, the longer time span a prediction covers, the more uncertainty it involves.

Usually models based on quantitative methods, which try to forecast the future accurately, have been the most common ones. However, they are criticized for their poor performance on long term forecasting. The results of pure quantitative methods have been particularly unsatisfactory in cases where there are complicated and surprising phenomena of the society involved. [3] One way of controlling the inherent uncertainty, that is always present when making predictions or forecasts, is to analyze various possible decisions, events and their consequences more closely. Scenario analysis is a technique that fills this requirement. Scenarios are alternative views of possible future events and their outcomes. It is different from predicting and forecasting in that the aim is not to produce only one correct outcome but to present many different alternatives by analyzing possible future prospects. Scenarios stress especially uncertainties which are not controllable. Thereby it is possible to better take into consideration the new unknown factors that a pure statistics-based model could never anticipate. Many long term forecasts are done by taking into account different scenarios, but to really harness the full potential of the approach, it should be possible to quickly and conveniently produce a series of "what if?" -type experiments. This way scenario analysis can be more of an everyday tool.

Moreover, the scenarios should be applied to the variables that have the most uncertainty.

Often the modelling of load growth as a whole is not based on realistic regional estimates. For example, two commonly used network information systems in Finnish electricity companies consider the load growth via global growth percentage which affects all the use sites and regions equally. [13][14] In reality the load growth can have high geographical variation and without considering the changes on more specific regional level the modelling error can be significant.

When it comes to modelling the electric customer behaviour, the prediction of hourly consumption habits of the customers is covered fairly well. Currently, approximated mean load curves are used for each customer group. In the existing situation the method is sufficiently good, especially when bigger group of customers are examined and the individual random behaviour becomes evened out. The current nearly static electricity pricing does not offer many incentives for the customers to change their behaviour in a frequent manner. More dynamic pricing of the Smart Grid vision is bound to make the task of predicting hourly behaviour more problematic. Load curves that are more dynamic will be needed respectively.

Something that various models often seem to be neglecting is a proper modelling of the new technology adoption which can significantly affect electricity consumption. For instance, modelling of electric vehicle adoption has been done extensively [12][15][16], but rarely seems to have been integrated in the electricity load forecasts with good spatial accuracy.

Economists have been using techniques labelled as geo-demographic analysis to classify people to segments by their socio-spatial characteristics. The theory of geo-demographics is based on a notion that knowing where someone lives provides useful information about how someone lives. There exists some relationship between people and places and between individuals and who they regularly meet. The renowned and widely accepted Tobler's first law of geography also suggests that: "Everything is related to everything else, but near things are more related than distant things". [4] Thus the spatial dimension should not be dismissed when modelling the consumer behaviour.

One of the most popular methods is to measure the technology's technical, geographical and economical variables to determine the potential adoption. [7][8] This derives from the fact that certain factors make the adoption of a product especially beneficial for the potential adopter. For example in the case of solar power, the amount of sun's radiation per year could be used together with the solar panel prices and effectiveness as factors that make the adoption more attractive on certain areas. However, such exact measures are not always easy to come by and there can be other factors, such as social, which are affecting the decisions leading to adoption or rejection. Consumers often prefer comfort,

practicality and familiarity to maximizing the cost effectiveness. As an example of this could be mentioned the popularity of using personal automobiles even though the public transportation would be economically more feasible in many cases. [11]

A method that approaches the problem of estimating product adoption by modelling the social factor has been used by Yang and Allenby. [9] The modelling of adoption is based on consumer preferences which are interdependent with the preferences of other people sharing some similar characteristics. An example case given in the study shows, that the preferences for Japanese made cars are related to geographic and demographic variables.

Hybrid energy–economic models such as the one by Jaccard & Dennis [11] have been made to integrate both the above mentioned economical optimization and the modelling of consumer preferences. Moreover, as the consumer preferences have a tendency to be dynamic by their nature, a consequent model which takes it into account has been made. The phenomenon of the changing consumer preferences, when the market is approaching saturation, is known as the “neighbour effect”. [12]

As a conclusion, more attention should be paid on modelling the adoption of new technologies that can have strong effect on regional electricity load, such as electric vehicles, heat pumps and distributed generation. Moreover, better spatial accuracy should be aimed for and especially in long term forecasts the uncertainty should be handled somehow. Neither the economical, technical and geographical feasibility nor the consumer preferences alone can explain the adoption of innovations realistically, but the combination has potential for more accurate results.

### **6.2.2 Tool for regional modelling of electricity loads**

A web-based tool for modelling regional electricity loads has been under development. The tool integrates ArcGIS server, a load model running in Matlab and Microsoft Silverlight web-application framework. It enables quick assessment of regional loads in different scenarios. As it stands, the tool allows selecting different areas from a map, inputting a scenario and getting hourly load profiles in a given scenario to inspect (Figure 23). The regional distribution of the loads can be further examined on a map.

The vision is to have a powerful tool which can be used to produce regional load forecasts in different scenarios and which supports decision making related to the planning of future electricity distribution systems. This can be achieved by an integration of various problem-specific models and environmental data. The latter can be possibly delivered from external information sources through open interfaces. Some planned features include: numerical and visual inspection of modelling results, comparison of scenarios and regions, load profile import (e.g. EV) and result export.

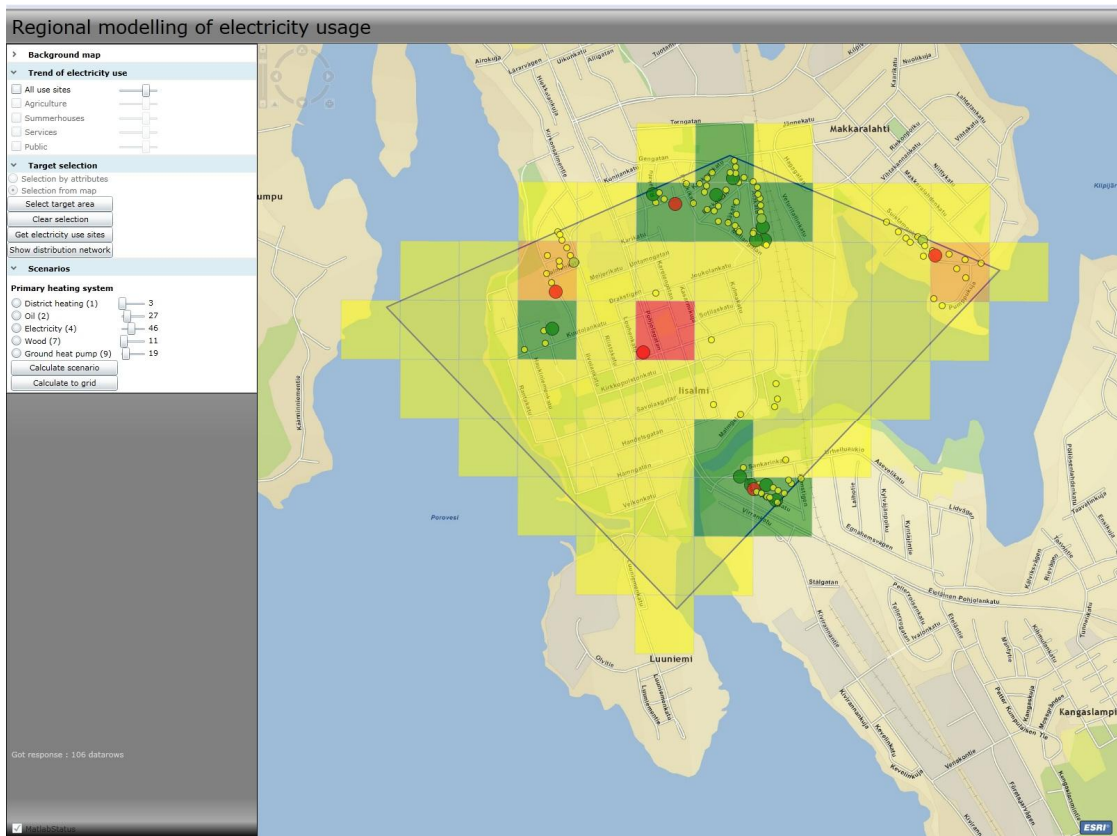


Figure 23 Regional modelling tool

## 6.3 Computational methods for regional modelling of electricity consumer behaviour and the consequent electricity loads

In this chapter the possible modelling approaches for predicting electricity consumer behaviour and the changes ensued in the electricity loads are speculated and analyzed. First the approach which has been applied until now is shortly described. After that new solutions are suggested and possible problems are brought up.

### 6.3.1 The modelling approach

Until now, a data-driven approach based on Self-Organizing Map (SOM) and multiple linear regression (MLR) have been investigated in the modelling of electricity load in different heating system scenarios. The modelling is based on VTJ building data derived from Population Register Center, Finland. The basic idea is to identify clusters and relationships between the building data and measured loads within customer groups classified into different heating systems.

An experimental evaluation on usability of the building data in analysis and modelling of loads has been carried out. The results show that while there are many beneficial features in the data, such as a high correlation of buildings' floor area, volume, number of inhabitants and electricity usage, it does not directly reflect the behaviour of consumers. More socio-economic data would be needed for that.

Calculations are on hourly level so that peak loads can be noted. The peak loads are important as they ultimately determine the needed capacity of the network. The model is built from independent sub-tasks. Firstly it must be somehow determined to which use sites or areas inside the area being examined the scenario is going to be applied. In other words, to select the use sites which have more potential for acting according to a given scenario. Secondly, new consumptions and load curves must be calculated for the sites that have been changed by the scenario.

The tool, for which the model is created, is designed for decision support where the user is usually an expert in the subject. It follows naturally that there exists some flexibility also for the user to make educated decisions and to try different possible scenarios. The scenario-based approach helps by decreasing the effect of uncertainty. It has a good chance to avoid the same pitfalls that a normal forecast could have e.g. with sudden and complicated changes in the society.

While modelling the emergence of new electricity consumers is important, the focus is now on modelling the behaviour of the existing consumers. Moreover, the focus so far has been mainly on detached houses as that is where the changes determined by the scenarios are more prone to happen. In the upcoming work these two issues should be dealt with to be able to make more extensive and accurate analyses. To obtain regional electricity loads that are realistic, it is necessary to include also apartment, industrial and commercial buildings.

The scenario input constitutes from the amount of adoption on a given area, which is then allocated to different sub-areas or use sites. This is based on a notion that the factors which contain high uncertainty are better to be handled with scenarios. Sub-areas inside an area should be configurable with separate scenario inputs to further control the uncertainty in the allocation.

So far applying the scenario to the electricity use sites has been done in a semi-random manner. The heating systems where changes can most probably happen are determined by expert configurable probabilities. Inside the heating system groups, the selection of the use sites is done randomly. Although the method has been functional, a new approach for allocating the scenarios and determining the adopters is necessary to further develop the model's accuracy. There are various ways to achieve this, which are discussed next.

### **6.3.2 Modelling electricity consumer behaviour**

Here a preliminary analysis and speculation is done on the ideas that could be used on modelling regionally the adoption of electric vehicles, distributed generation and heat pumps. Further along the line, a more in-depth analysis is going to be necessary on how to concretize and implement the ideas in the regional modelling tool presented in chapter 6.2.

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It is a common way to differentiate modelling methods between data- and knowledge-driven. In data-driven methods it is typical to use empirical approach so that the best parameters for the model are found through iterative process of try and repeat. As for the knowledge-driven methods, an expert uses his experience and knowledge to choose the model the best possible parameters. [10] The use of data-driven method enables to model without necessarily knowing exactly all the individual factors and their interdependencies that influence the outcome. At the same time the results have potential of being more objective and the method has more chance for being generally applicable to different types of data and subjects of modelling. In other words, the level of automating the whole process of modelling can be higher. For the above-mentioned reasons it is desirable to have a modelling approach which mainly leans on data-driven methods. On the other hand, it is crucial to have data that is of good quality and quantity.

As was discussed earlier in chapter 6.2, the consumer behaviour can be predicted at least partly by using the spatial and socio-economical features of an area. This could be done by using literature to label the areas by their potential. However, this would involve the loss of benefits provided by the data-driven methods.

Another possible way is to measure the innovation's economical potential in each area and optimizing the output to determine which areas would gain the biggest benefit. Accurate measures can be made as long as sufficient information is available. However, this would necessitate deeper knowledge about the problem to recognize the attributes which affect the economical feasibility, and again the benefits of data-driven method would be lost.

One example of applying data-driven method would be to empirically recognize the characteristics of the adopters from the data and then finding candidates that share the same profile. On the other hand, the consumer preferences cannot be easily revealed from the existing data because the behavioural patterns describing the adoption of an innovation in actual market transactions still do not exist. Moreover, a data that describes the consumers' stated preferences, such as an enquiry, might not reflect the reality because the consumers do not always do what they say they will. [11] However, using the revealed preferences consumers have on existing products that are similar to the innovation in their characteristics, offer same type of benefits or appeal to consumers with same type of mindset, it could be hypothetically possible to reason the consumer preferences on the innovation. For instance, the potential for reflecting the current adoption of hybrid electric vehicles to the adoption of the plug-in hybrids should be investigated. Using the stated preferences acquired for example from an inquiry could be used with the precaution that the stated preferences as such might not strictly transfer to actual behaviour.



When predicting consumer behaviour, from which little or no data is available, some knowledge about the factors affecting the phenomenon being predicted seems inevitably necessary. As the consumer preferences have significant influence on the behaviour but some technical and economical obstacles might exist for some consumers, which cannot be seen from the stated preferences, a model which takes these two facts into account will be essential. Nonetheless, some questions still remain open, for instance, how to implement the consumer preference dynamics.

### **6.3.3 Incorporating load curves to the model**

The actual electricity usage can be modelled with load curves which represent the hourly consumption profile. After having predicted the consumers who are adopting electric vehicle, heat pump or distributed generation, the existing load curves must be somehow modified to acknowledge the transition respectively. If the electricity load profile over one day is known for the new appliance introduced, it is possible to add this profile to the existing one to have the new overall consumption.

Whether the subject that adopts the new appliance or technology is a single use site or an area the adding operation functions with certain limitations. The possible limitations include the fact that the load profile for the new appliance must be a generalization of the actual profile because the exact usage patterns which can have high random variation would be impossible to predict for every specific case. Nevertheless when modelling bigger area the effect of the random variation is evening out and the actual usage patterns become closer to the generalization. The more actual information exists for the effects that comprise the electricity load profile, such as the windiness could be in the case of distributed wind generation, the more accurate these curves can be and less generalization will be necessary.

The best situation would be if individual load curves would exist for each electricity consuming appliance. When adopting a new appliance, getting rid of or changing some existing one, these curves could then be added and removed from the overall profile accordingly. The same principle could be used for calculating the overall load curves for bigger area. Summing up the individual load curves inside an area would give the overall general profile. However applying statistical methods for capturing the real load spikes and for accommodating the scattering of the loads from individual use sites would be necessary.

### **6.3.4 Summary of computational methods**

A preliminary investigation on potential computational methodologies for acknowledging the consumers' adoption of innovations that can significantly affect the regional electricity loads is presented and a basis from where to carry on with further experiments is created. Modelling both the consumer preferences

and the regional potential for adopting an innovation is suggested. Moreover, it is fundamental to have data that describes the aforementioned circumstances. The model accuracy is highly dependent of the amount and quality of the data. The growth and expansion of the population and more dynamic electricity pricing are some of the elements that should be included in the model to have more realistic predictions.

## **6.4 Data usability and the potential data sources for modelling electricity consumer behaviour**

This chapter provides an insight on what type of data would be necessary to carry out the modelling and what information would be desirable for it to include. Moreover, an overview of potential data sources has been done.

### **6.4.1 Required data and background information**

In data-driven models, a deep understanding of the variables contributing to the matter being predicted is not as important as, for example, in qualitative models. Though, it is not to say that no knowledge is needed to be had about the problem in hand. Data of as high quality and quantity as possible enables the model to better capture the patterns of the phenomenon that is being modelled. Data from different sources can be combined to fill in the missing and insufficient information (Figure 24). As a result the model becomes more robust. The performance of data-driven models in general tends to correlate with the data quality. In any case, data that is explicit and describes the phenomenon being modelled is an absolute necessity to have any meaningful results. The regional electricity consumption can vary because of changes in the amount of electricity users in the area or because the magnitude of the existing users' consumption grows, as mentioned in chapter 6.2. Therefore, data that somehow expresses these two phenomena is needed.

The first and foremost data to be needed are the hourly consumption profiles. Ideally there would be hourly consumption measures from every electricity use site. As often that is not the situation, generalized load profiles have to suffice. The consumption data can be provided by the electricity companies.

Because of the model's approach, it is relevant to have data that provides knowledge about what kind of consumers have the most potential or are most probably changing their electricity consumption behaviour through the adoption of new technologies. Predicting the adoption of the innovations requires information that reveals the consumer preferences and the practical benefits technology can offer on certain areas or to each individual consumer. Therefore, stated or observed data is needed to capture the consumer preferences. To measure the technologies potential the relative capital and operating costs must be known including for example the fuel prices, government subsidies and tax benefits. Furthermore, the information about possible geographical and legal

blocks for adopting the innovation is needed. Statistics about the current adopters of the technologies being examined could be used to identify features that enable or encourage the adoption.

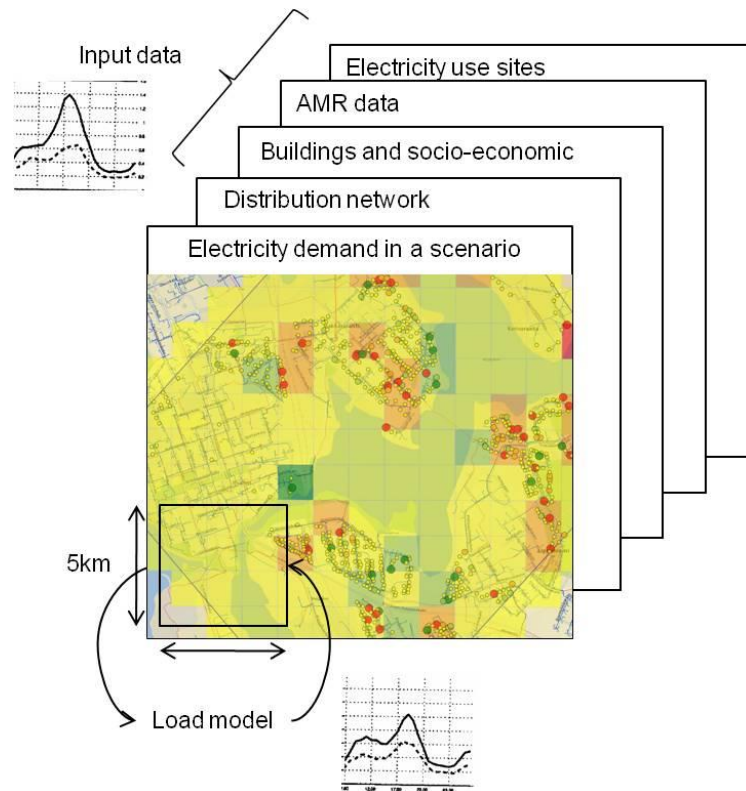


Figure 24 Combining different data inputs for modelling the regional electricity loads

#### 6.4.2 Overview of potential external data sources

This section provides a preliminary insight on external data sources that could be used in regional modelling of electricity consumption, specifically with data-driven methods in mind. A more profound analysis is necessary to measure the explanatory features of the data provided by each source. In this case the external data sources refer to the environmental information that is available from public and commercial registers. The list is not definitive, but attempts to cover most promising sources that might have some use for the task at hand. It is in addition to the more specific information not readily available such as the inquiries or databases which electricity companies maintain. During this project an inquiry has been made to find out about the consumer preferences regarding Smart Grids. For instance, the results provide stated preferences the consumers have on acquiring an electric vehicle, a heat pump or some form of distributed electricity generation. Moreover, electric companies produce big amounts of usable information to different databases such as customer and network information systems. Following has a brief description of the potential data sources which could be usable.

*Population register centre, Building and dwelling register*

Building information is available from Population Register Center. It is maintained by municipal building supervision authorities and updates are typically applied when a modification requiring permission is made. As such there is no guarantee that the information would be up to date in every case. Building information has the benefit of having high spatial accuracy but alone it cannot be used to predict the consumers' behavioural patterns for which also socio-economical data is needed.

*Statistics Finland, Grid database*

Statistics Finland provides a grid database which includes various socio-economical variables for areas with resolutions of 1 km x 1 km and 250 m x 250 m. The variables describe population's structure, education, main type of activity and income, households' stage in life and income, as well as buildings and workplaces. For privacy reasons some grids might have hidden information if the amount of cases per grid is not above a certain limit. The missing information however could be possibly estimated with the help of other databases. The socio-economical variables provided by the database have good potential to be used for predicting the consumer behaviour. Additional data which describes the consumer preferences is still necessary to perform the modelling.

*Finnish transport safety agency, Vehicular and driver data register*

Finnish transport safety agency has registers of all the cars in Finland. Among the information included are for example the vehicle owner and the vehicle type. The information cannot be obtained directly from Transport safety agency, but their partners who distribute the data in various forms should be used instead. Information about all the vehicles registered and their types per area could be used to predict the most promising areas for electric vehicle adoption. However, privacy policies can prevent obtaining such data and it might become costly.

*Finnish meteorological institute, Location specific temperature statistics*

Location specific temperature statistics covering whole Finland between years 1971 and 2008 are provided by the Finnish meteorological institute. The historical temperature statistics can be helpful in predicting the regional electricity loads as they are highly dependent of temperatures. The data is available for free for research purposes.

*Ministry of agriculture and forestry, Agricultural statistics and registers*

Agricultural registry is maintained by the ministry of agriculture and forestry. The registry contains various type of information on Finnish farms. For instance,

included are the amount of animals and cultivated area, which could be used to calculate the potential for bio gas based electricity and heating.

*Finnish environment institute and the regional councils, Regional land usage plans*

Finnish environment institute has collected all the valid regional land use plans from the different regional councils. The land use plans include information such as land use reservations and areas suitable for wind power. The data could be used to predict the locations of new electricity use sites or to locate upcoming wind power.

*National land survey of Finland, SLICES land usage information*

SLICES registry attempts to describe whole Finland's usage of areas. Separated are for example the residential, commercial and industrial areas. The information can be usable in predicting the locations of new electricity use sites or as an additional information source in predicting the regional adoption of distributed electricity generation, heat pumps and electric vehicles.

## 7 Discussion and conclusions

The results of the studies carried out in the work package represent different approaches to consumer behaviour concerning Smart Grid technology. The common goal of the studies has been to produce knowledge that can be used to facilitate and enhance the consumers' adoption of the Smart Grid system.

One part of the work has been focused on consumer acceptability of Smart Grid in order to gain a preliminary conception of factors that are relevant from the consumers' point of view.

The main advantages of Smart Grid systems planned for households are on-line data of the instantaneous hourly energy consumption, possibilities for controlling the consumption and possibility for distributed generation. The measures to achieve the energy efficiency and energy saving targets are demand response and dynamic pricing.

Advantages and barriers of Smart Grid have been explored on the basis of exploring the consumers' opinions and expectations of their usage of energy and Smart Grid technology. The knowledge gained from these explorations brought out both expressions of interest in issues concerning use and saving of energy and different kinds of concerns and doubts.

According to the results of the investigations of customer service interactions at an energy company in Finland and Sweden customers have a low level of knowledge about their electric installations and responsibilities concerning safety issues and ownership. They are also uncertain of the information given in their electricity bills. They are interested in the status of the power grid regarding service work, disturbances in power delivery and often just what is happening at the electricity company and in the grid. As to matters concerning use of energy the customers mainly do not want to see the connection between their electricity consumption and their habits of action. The customers are interested in the frequency of the meter readings and the way the meters are functioning. They would like to acquire more informative readings on their energy consumption in order to be able to see how the consumption is distributed at their homes and expect more of the displays.

The answers of the inquiries show that in Finland heating is very important for the consumers. The additional heating is in use and changing the main heating system has been planned in several cases. The electric heating was found a load which could be switched off for one or two hours especially in exceptional cases. Other energy saving measures listed in the inquiries have been already realized or the respondents found these measures possible to carry out. In general the respondents were interested in monitoring and controlling their consumption. The barriers on the consumer side related to switching off the heating or cold appliances by remote control, the safety in remote controlling, data security and

privacy protection. The consumers are worried about safety or undesirable consequences of on/off switching of appliances. Doubts on the privacy and data security considered were such as the real time consumption data could find its way for criminal purposes. Most respondents were not willing to pay for the consumer feedback services based on information enabled by Smart Grids. Some respondents also mentioned fears of damages in appliances caused by automatic control.

Introduction of Smart Grid as a new innovation has been discussed by considering Smart Grid and Smart House, especially the AMM meters and displays, in the light of Rogers' model of diffusion on innovations. The consideration has been made by using Rogers' categories which characterize innovations with the help of the concepts of relative advantages, compatibility, complexity, trialability and observability of an innovation.

The provision of information to the consumers within the Smart Grid technology has been reviewed by considering instances of lack of knowledge and understanding among the consumers, concerning, on one hand, use of energy and energy efficiency and, on the other, the Smart Grid concept. The ways the consumers perceive and comprehend these issues influence their trust on and acceptance of the technology. Implications on the basis of the review point out the consumers' need of information, the identification and definition of which is not always straightforward. There is need of information that would contribute to reducing the experienced complexity of the Smart Grid system, enhancing trust on the concept and technology and facilitating the use of the system. In addition to the customary information needs, the consumers need contextual and background information and information that makes it possible to understand bigger wholes, causal relationships and influences and also uncertainties and risks.

The crucial importance of the quality of information for the acceptability of Smart Grid technology and, consequently, for the adoption and success of the system, poses challenges to the development of and communication on the Smart Grid concept. Meeting these challenges requires adoption of a contextual and system's view on the concept, not only in the technical and economic sense but also in the "human sense". This means taking account of the consumers' view by 1) regarding the consumers as active, interactive and equal parties in the human actor network and 2) paying attention to the potential constraints in the consumers' possibilities of knowing and understanding the relevant issues concerning their use of energy and the Smart Grid concept.

The developers of Smart Grid technology could focus on identifying the consumers' needs of information on the basis of systematic cross-disciplinary collaboration of experts from relevant fields, including human sciences, and representatives of different consumer groups. Development of use case descriptions for taking a closer look at the consumers' demands for

understanding the relevant issues and for defining the consequent information needs would contribute to provision of information that can reduce the consumers' lack of knowledge and understanding.

The actors in the electricity business could pay a special attention to the way of communicating on Smart Grid technology to the consumers. The abilities and final needs for adoption of the Smart Grid system of an individual consumer differ from those of the other actors. There needs to be a common language in which the information is expressed. This, however, poses another challenge since there is lack of knowledge and uncertainty on the characteristics, functioning and entirety of the Smart Grid concept also in the electricity and energy companies, due to the complexity of the concept.

Consumers' adoption of Smart Grid technology could be supported by creating sufficient prerequisites for enhancing their energy awareness. This means developing interventions and services for personal advice that give the consumers possibilities to comprehend the relevant issues, concerning the new technology, in practice, as applied to their own environments.

The other part of the work carried out in the work package has involved laying a groundwork for developing a computational data-driven method to predict regionally the consumers' adoption of smart grid related innovations and the consequent effects it has on the electricity loads. The innovations considered include, for instance, plug-in electric vehicles.

To model the behaviour it is important to have data that is of good quality. In the case of innovations, proper data is hard to come by because, after all, the innovations might have just entered the market or might have not yet entered at all. In the absence of proper data derived from actual market transactions, examining the consumers' adoption of similar innovations, which have been in the market for longer, could reflect the consumers' innovativeness and willingness to adopt also the new innovation. For instance, the potential for reflecting the current adoption of hybrid electric vehicles to the adoption of the plug-in hybrids should be investigated further. Moreover, modelling both the consumer preferences and the benefits given by the innovations in certain regions is suggested by the literature.

A fundamental aspect is to have spatial data that is up-to-date and high quality. It is often difficult to come by and can be very costly. However, the current trend seems to be that the different information repositories of the society are slowly opening up for free public use. At the moment, the Grid Database of Statistics Finland seems to be adequate for capturing the regional socio-demographic features. Information sources such as the vehicular data from the Finnish Transport Safety Agency could be used as a starting point for modelling the electric vehicle adoption. A model based on this methodology will be constructed



and integrated to the web-based regional modelling tool during the next periods of SGEM.

This report presents a preliminary view of the opportunities that introduction of Smart Grid technologies could bring for household consumers and aspects influencing its adoption. The impact of SGs on household consumers is mostly produced by accurate information on electricity usage and new services enabled by it. Small-scale inquiry and interviews conducted in this study indicate household consumers' interest on appliance-specific information on electricity consumption, whereas reforms of pricing of electricity and automatic control of appliances seem to be of interest to a lesser degree. Concerns about data security and safety and fears of damages caused by automatic control of appliances can be considered as barriers that might be relevant to be taken into account in further research and development of Smart Grids. The presented considerations on communication suggest that there is need of common concepts and language and cross-disciplinary collaboration among the developers of the technology and the electricity and energy companies for meeting the challenges of improving the quality of information provision in the context of Smart Grid technology.

## 8 Reports and publications

Reports and publications related to the work package SGEM WP 1.2 in production (publication date):

1. Anna-Karin Back, Involvement of Smart End-users in a Smart Grid, Master's thesis, Vaasa University, c.a. 100 p. (Q1/2011)
2. Preliminary accepted CIREC paper: Niska, H. et al., Scenario based electricity load prediction tool for distribution planning and management, 4 pages. (June 2011)
3. Jarkko Tiirikainen & Jukka Saarenpää, University of Eastern Finland. Regional modelling pilot application, including modelling of electricity loads on hourly scale. (February 2011)

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## Annex 1

It was possible to give additional free form answers to some question groups of the web inquiry.

### A. Comments regarding the heating systems:

*Do you use additional heating? What type?*

- 1 *Wooden stove*
- 2 *Electric floor heating in bathroom*
- 3 *Electric floor heating*
- 4 *Wood-heated boiler, fireplace, wooden stove*
- 5 *Electricity*
- 6 *Electric heater*
- 7 *Most of the winter with the fireplace*
- 8 *Electric storage heating.*
- 9 *Mains supplied computer*

*Have you planned changing your main heating? What type?*

1. *No*
2. *No*
3. *No*
4. *Ground heat, rock*
5. *Electric floor heating*

*Have you planned additional heating? What type?*

1. *Electric heater*
- 2 *Wind*
3. *Wind power*

### B. The free form answers for the “other” reason for not buying an electric vehicle:

*I will not buy an electric car, because...*

- 1 *Diesel car is still reasonable*
- 2 *I would not get firewood home. They will stay somewhere in Mäntsälä*
- 3 *I don't need a car*
- 4 *I don't need a car*
- 5 *I don't need a car at all*



- 6 *I don't need now*
- 7 *I don't need now or ever*
- 8 *I have no car and I will not buy*
- 9 *Electric car is inconvenient in use*
- 10 *Electricity is more expensive than gasoline*

C. The free form answers concerning consumer interfaces:

*What kind of information would you expect from display/control device? Other, what?*

- 1 *don't know*
- 2 *Sometimes, when the own device fails it would be good to know if the device is energized or not. Earlier it was known by disconnecting the fuse links and watching how the disc of the meter was rotating. Now it is not possible. The meter could be provided with a display showing an instantaneous power. Now it measures, but does not display.*
- 3 *Home/absent switch*
- 4 *Appliance specific consumption'*
- 5 *Instantaneous power*
- 6 *Other information produced by the equipment, like temperature or whatever the user will think*
- 7 *Energy and distribution separated: specified pricing information*
- 8 *Both energy and instantaneous power is interesting*
- 9 *Increase of energy price in advance*
- 10 *Information about those developing actions that will lead the electric company to reduce both energy and distribution price*

D. Free comments were asked for the following questions about possible dangers or disadvantages caused by the control as well as about data security or losing the privacy protection..

*Are you afraid that the control would cause disadvantages or danger? You can write here as many aspects you want to.*

- 1 *Of course the electric company could notify and suggest suitable times for taking a sauna or washing, but it cannot set the moments for electricity utilization*
- 2 *Power quality gets worse, peaks/harmonics*
- 3 *17 degrees or less starts to be a bit chilly. It means if the batteries are switched off for one hour it starts to be cold. Cold appliances: What about food conserving??*
- 4 *Don't know*

- 5 *Controlling is merely the interest of the electricity company. I will not have anything to do with that company.*
- 6 *I always and everywhere oppose the better knowing outsider's knowledge on what is best and correct for me.*
- 7 *Not afraid*
- 8 *Operating reliability; control actions; problems/complexity; supply security, costs*
- 9 *The user may think that the device X is not on though it is controlled by an automation system. Unexpected later start might cause a danger. Thus only switching off could be automated and switching on could be done only by the user.*
- 10 *I have years ago agreed (forced to agree) in my electricity contract in switching off the electricity. Why to ask it any more. The only load that can be switched off is the heating. Other loads mentioned in the previous question will confuse the work in households. For instance switching off the cold appliances just after strawberries have been stored in the freezer will make the housewife angry*
- 11 *Keeping in mind different control actions could make a normal life difficult: which device is working and when and which one is not*
- 12 *I myself would like to be able to control my electricity consumption.*
- 13 *Disadvantages*
- 14 *I don't think that it will help in savings, many things would be missed; not a certain method*
- 15 *Does it mean that cold appliances would first be switched off and food will be left there and go bad.*
- 16 *I need electricity as the aid facilities operate with electricity, I am 100 % invalid*
- 17 *I will not support controlling by the electricity company, because the control is learning and practice, in which "some actor" will manage such forms of life, who's business it cannot and may not be.*
- 18 *No*
- 19 *Cold appliances cannot be suddenly switched off and later switch on. Then food in the freeze will go bad.*
- 20 *The house build in 1924 some hours without heating: I don't think it is a good idea.*
- 21 *I'm afraid if there is lacks in operation; and how it will work in fault cases.*
- 22 *I my opinion the cold appliances will not withstand the interruptions*
- 23 *The distribution company could control the loads automatically, if the customers would have a) a possibility to cancel it and b) a knowledge of those actions in beforehand. The retailer could control the heating load during the peak price, but otherwise the customer should be able to control the flexible price him/herself*
- 24 *It is a bit unclear what he last question meant - so, the electricity company would decide when I put the television on? It does not sound very practical*

25 *All integrity will be lost; will anything be saved, all devices should be planned to a+++*

*Are you worried about data security or losing the privacy protection, if you will give your electricity consumption data? Yes, what?*

- 1 *no answer*
- 2 *no answer*
- 3 *don't know*
- 4 *For instance, who would want a energy-guzzling partner into the housing association*
- 5 *For instance burglars could analyze my absence*
- 6 *For instance, falling of the basic temperature during the long absences, like travels*
- 7 *Electricity company cannot rule the subject*
- 8 *How the consumption could be monitored more exactly? The customer has right to receive the hourly readings anyway, and AMR meters are not capable to measure energy consumption more accurate...*
- 9 *All the time someone is watching what I'm doing*
- 10 *The question is not good as the points in question are data security and privacy protection*
- 11 *When you ask, so it is possible that someone who has access to my consumption data will inform criminals: home, not home*
- 12 *OK, as long as the information is statistics and not for instance real time monitoring: like when the habitant is at home (or is not!)*
- 13 *Orwell 1984*
- 14 *Electricity price is all the time increasing*
- 15 *Electricity price is all the time increasing, internet use, facts, banking services, security*
- 16 *The remote electricity meter measures my consumption at each moment. Electricity company could not change over from the estimated invoicing, although remote metering would allow it. I think that developing even more sophisticated services are only daydreams of engineers, which never will be finished.*
- 17 *Data leakage*