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Market Based Demand Response Research Project summary

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RESULT (summary)

This report summarizes the main results and contributions from the "Market Based Demand Response" project (2005-2008). The project has been organized in three work packages with the following focuses: WP 1: Measures to increase the demand side price elasticity, WP 2: Technology and quality improvements in the "meter value chain" from the meter to the electricity bill and WP 3: International development through participation in the IEA/DSM project "Demand Response Resources".

One of the main aspects in this project was to encourage demand response to the marginal price in the electricity markets. Spot price energy products and Time of Day (ToD) tariffs have been used both for households and for larger customers. The principles and reason for the choice of tariffs are explained in the report.

The following pilot tests involving households and medium sized customers have been carried out: a) "Fixed Price with Return options" energy contract, b) Remotely controlled load shifting, c) "Smart house" control in housing cooperative, d) Low prioritized loads controlled by building energy management system (institution and shop) and e) Automatic Demand Response to the electricity spot price.

The Norwegian authorities have now decided that "smart meters" should be installed to all customers in Norway within 2014. Experiences from full-scale implementation of systems for automatic meter reading (AMR) have in this context been collected and described, and a specification of requirements for AMR systems is developed in cooperation with a group of network owners. Definitions of how to measure quality and availability of hourly meter data within the settlement period is proposed by the project.

The main recommendations from the project:

I) Temporary reduction in space heating and load shifting of water heaters are the most convenient demand response objects in Norway II) Frequent metering is needed to secure that the responsive customers really get lower bills in periods with high prices III) ToD network tariff combined with hourly spot price provide the customers with a dynamic price signal that gives incentives to needed investments and to load reduction in peak hours IV) Rational implementation of remote and/or local control options should be considered as a part of the coming AMR projects V) Quality requirements should be included in the directions from the regulator VI) The requirement specification developed in the project is recommended as a basis for tenders VII) Nordic cooperation in the Nordic AMR Forum should be prioritised VIII) The investments in AMR systems need to be followed up by dedicated programs with focus on how to respond to price variations, preferably combined with information about the environmental impact (CO_2 emissions etc.).

KEYWORDS

SELECTED BY AUTHOR(S)		
	Demand Response to price	Load shifting
	Meter data quality	AMR requirements

TABLE OF CONTENTS

1 INTRODUCTION

This report summarizes the main results and contributions from the "Market Based Demand Response" project (2005-2008). The project has been included in the RENERGI[1]-program of the Research Council of Norway.

The Norwegian Transmission System Operator, Statnett SF, has been responsible project owner on behalf of the stakeholder group comprising EBL (The Norwegian Electricity Industry Association), NVE (The Norwegian Water Resources and Energy Directorate), Statsbygg (The Directorate of Public Construction and Property), Distribution System Operators (DSOs), power suppliers/retailers and vendors of technology for automatic meter reading and load control.

The research has been carried out by SINTEF Energy Research.

The documentation worked out in this project, is mainly in Norwegian (see reference list on page 40). This was a motivating factor for this summary report in English.

[1] RENERGI = Clean Energy for the Future

2 PROJECT DESCRIPTION

The main goal of the project has been to:

"*Stimulate to increased demand side flexibility and thereby contribute to a more efficient power market*"

The project builds on knowledge from previous projects testing different Automatic Meter Reading (AMR)[2] systems and the load curve impact of different price signals [20], [21].

The research agenda for the project was defined in an initial workshop. It was agreed that the work should focus on the following aspects:

- Present demand side price elasticity and efforts of improvement
- Customer acceptance – surveys and questionnaires
- Identification of low prioritized appliances and by that the most suitable load control objects
- Pilot tests based on the experiences from the recent Demand Response activities
- Meter data quality assessment and measures to improve the data quality
- Meter value chain (from meter to billing) efficiency
- Maintaining the international link via the ongoing IEA/DSM project "Demand Response Resources" (DRR)[3] by including the Norwegian DRR-project as a work package

Note that the demand response efforts are situational and aiming at changes in "*electricity usage by end-use customers* ***from their normal consumption patterns***"[4] and does not include traditional energy conservation, which has a more permanent character.

2.1 BACKGROUND AND MOTIVATION

The forecasted shortage in both peak load capacity and electrical energy in the next 5-10 years was the main motivation for this project. Increased demand response in the power market is both nationally and on Nordic level regarded as a promising, and potentially cost effective, alternative to investments in new production and transmission capacity.

After the 2002/03 winter with high prices caused by low precipitation, the Norwegian Ministry of Petroleum and Energy issued a White Paper on the security of supply [22]. Improved end-user contracts and efficient use of AMR and Remote Load Control (RLC) were among the various measures mentioned in this paper to mitigate a tight future energy situation.

Achieving a well functioning interplay between the monopoly actors and the market players is regarded as important. The DSOs who are responsible for metering and billing has a central role as facilitators for the market, and the challenge for the suppliers is to adapt and develop the end

[2] Also called two way communication, which implies that signal can be sent two ways
[3] http://www.demandresponseresources.com/
[4] Quote from Department of energy report, USA, regarding demand response (2006)

user contracts in view of the opportunities given by the introduction of smart metering and load control options.

Figure 2-1 shows the main actors related to Demand Response (DR), grouped as monopoly and market participants. There is an overlap between the groups where Statnett (TSO), which is a company under monopoly regulation, has a role as organiser of the Regulation Power Market (RPM). The Nordic power exchange, Nord Pool, is the organiser of the" Elspot" day ahead market.

The customers receive both a network tariff from the monopoly side and an energy contract from the market side as indicated on the figure. The technology providers are included in the figure because of their important role in developing and offering new and functional equipment for metering and load control.

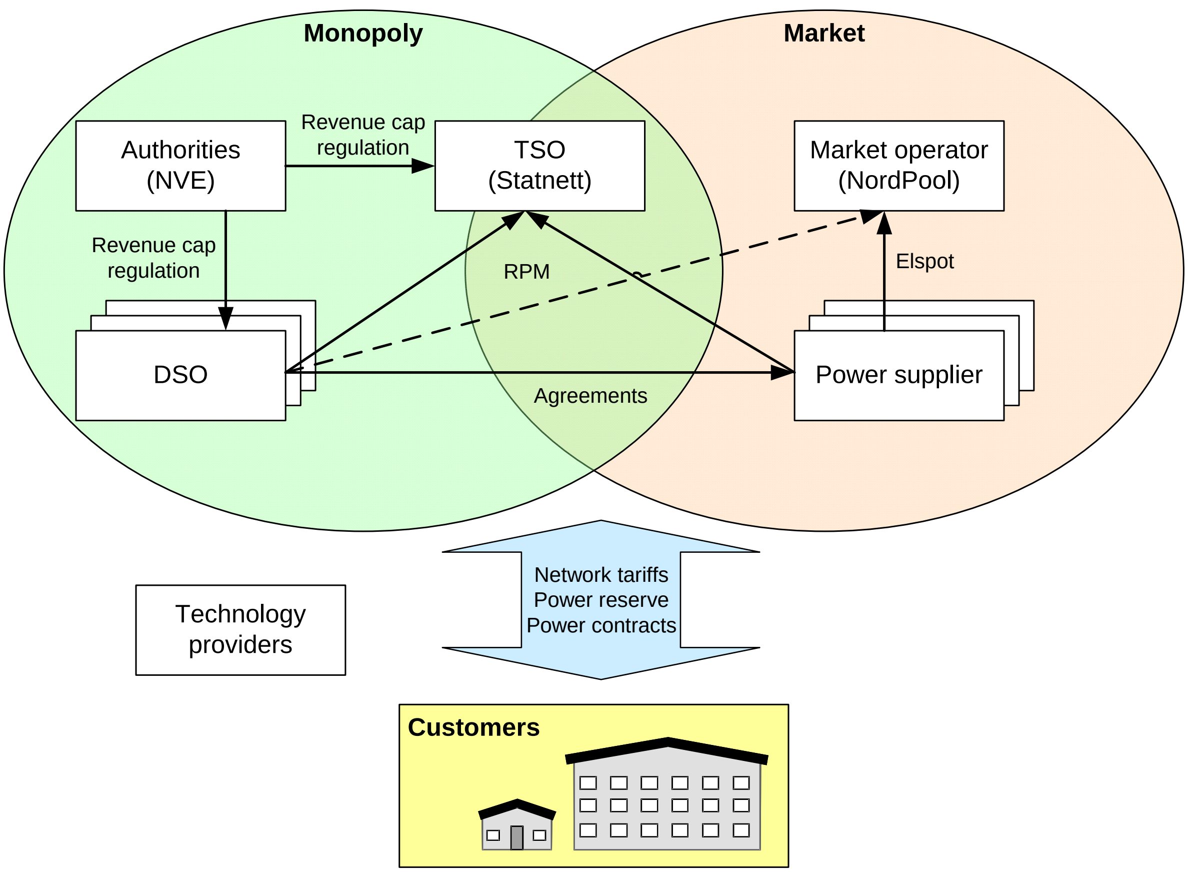

Figure 2-1 Involved actors and relevant relations

2.2 POTENTIAL BENEFITS OF DR FOR INVOLVED ACTORS

The following potential benefits for the involved actors can be achieved:

The flexible customers will improve their energy economy when consumption is reduced in periods with high prices.

Distribution System Operator (DSO): DR can reduce bottleneck problems in the distribution system, and the DSO can benefit from reduced system losses by load reduction in the peak hours. Customer satisfaction can be increased, and new AMR/RLC services for customers and/or for suppliers can be commercialized in the future.

Power Supplier: The customers are free to change supplier, which stimulates to a more efficient competition. Development of new and attractive contracts for electricity with incentives for load reduction when the prices are high can therefore be a competition advantage for the suppliers. There is also a potential for reduction of the volume risk in high price periods.

Transmission System Operator (TSO) is, among other tasks, responsible for facilitating a well functioning electricity market. Increased demand side participation is an important part of the market development and also a source for power system operation improvements.

Technology manufactures and vendors: A great volume of smart meters is expected to be installed in a few years horizon. Development of new commercial products e.g. for price dependent load control might additionally have a large international market potential.

2.3 WORK PACKAGES

The project has been organized in three main work packages (WP) as shown in Figure 2-2.

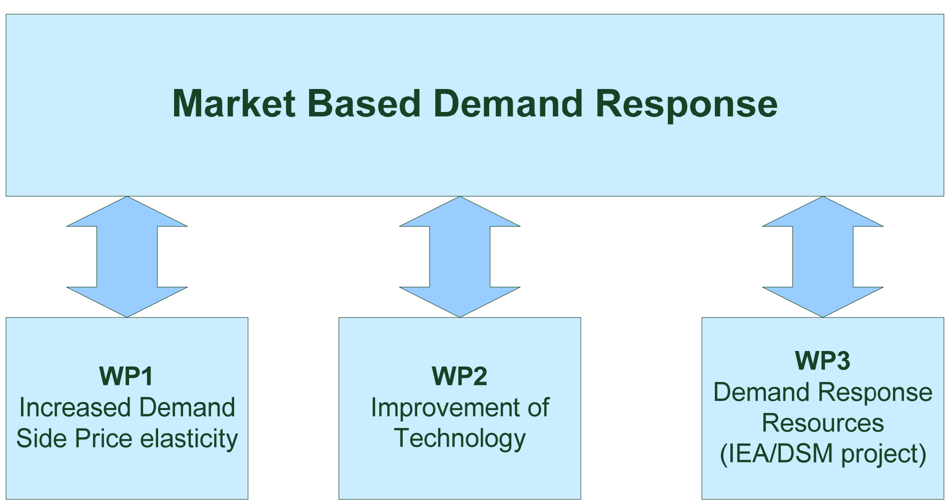

Figure 2-2 Project organization

2.3.1 WP 1 "Increased Demand Side Price Elasticity"

Objective: *In a customer friendly way to motivate to flexible use of electricity in periods with shortage of energy and/ or power*.

Main contributions:

- Market Based Demand Response. Preparatory study [13]
- Survey regarding technology for hourly metering and two way communication [12]
- Discussion of factors affecting the price elasticity [11]
- Description of low prioritized appliances as a resource for the network owners and the power market [3]
- Description of the following pilots with focus on customer response and change in consumption pattern [1]:
  - Fixed Price with Return options
  - Remote controlled load shifting
  - "Smart house" control in housing cooperative
- Potential limitation of the deficit in Mid Norway by encouraging demand response [18]
- Overview of commercial local load control options [19]

2.3.2 WP 2 "Improvement of Technology"

Objective: *Measure and document the changes in consumption and contribute to quality improvements and efficiency in the "meter value chain"*.

Main contributions:

- Data format and quality requirements in the meter value chain [6]
- Analysis of availability of hourly metered data [7]
- Experiences from full-scale establishment of AMR [8]
- Specification of requirements for full-scale AMR tenders [9]

2.3.3 WP 3 "Demand Response Resources"

Objective: *Provide input to and exchange experience with the international DRR-project and to demonstrate Norwegian technology and market based solutions for demand response.*

Main contributions:

- Descriptions of Nordic market mechanisms and ongoing DR related activities in Norway
- Assessment of the value of load shifting in Norway based on historical data [10]
- Demonstration of Automatic Demand Response (ADR) scheme by utilisation of web based interface for definition of control parameters and radio based remote control of water heaters [2]

3 DEMAND RESPONSE TO PRICE

One of the main aspects in this project has been to encourage demand response to the marginal price in the electricity markets. This means in principle that the reducible loads should respond when the price exceeds the customers' willingness to pay, which in practice can be done by systematic load reduction when the price is high over a period of days/weeks, or as a response to the price in the peak hours.

The most important socio economic benefit from increased demand side participation in the market is the potential of load reduction in periods of shortage, which e.g. reduces the need for investment in new production and/or transmission capacity. The exact value of the benefit is difficult to calculate because the price reduction achieved affects all the players in the market, and some actors, e.g. the producers, will loose money.

However, the example from the California crisis in June 2000 is a good illustration of the value of demand response: The market prices rose to up to 10 times historical level, rolling blackouts were instituted and bankruptcy of several institutions occurred. This shows that the cost of shortage can be enormous. According to [25] only 300 MW load reduction (out of a total load of 50 000 MW) for a few hours would have been sufficient to avoid the rolling blackouts.

3.1 IMPROVED MARKET PERFORMANCE

From the point of view of a well-functioning market it would be beneficial if a major share of the customers had spot price contracts on hourly basis, which is the shortest settlement period in the Nordic market. When customers learn how to adapt to varying prices in the short run, this would also increase price elasticity.

In a shortage situation with steep bid curves in the Elspot market, a small price dependent load reduction can result in a substantial drop in price, and in some cases avoid rationing and secure an initial balance. Adequate demand response in the peak hours will not only reduce the high prices, but also the average price over the settlement period. This means that all customers would benefit from the reduced price, and the customers who are contributing by systematic load reduction, would have an extra benefit due to the reduced consumption in these hours.

The Elspot price will only be correct if the planned and known price dependent reductions in consumption are bid into the market in the same way as the bidding of the production units. Load reduction not bid into Elspot might result in wrong initial production/ load balance. This can lead to unnecessary balancing costs and in extreme situations to failure with regard to price determination.

The vital point in this context is to provide the consumer with economic incentives that reflects the actual market situation. Development of new energy products from the supplier side and network tariffs that are adapted to the possibilities the more frequent meter reading and load control options provides, is therefore a basic focus area.

3.2 PRICE SIGNALS TO THE CUSTOMER

Experiences and customer surveys show that potential reduction in the electricity bill and the growing focus on environmental issues are the most important factors of motivation for a more flexible use of electricity. The price signal to the customer is in other words important, and so is also the message that load reduction, especially in the peak hours will lead to reduced CO_2 emission[5].

In the Nordic deregulated power system all customers have separate tariffs for the energy and the use of the network:

- The energy part is based on a contract between the supplier/retailer and the customer. The customers are free to choose between a number of retailers who offer different products in open competition with each other.
- The design of the network tariff can vary within the framework defined by the Authorities as a part of the monopoly regulations.

3.2.1 Development of supplier products

The suppliers are the “mediators” between the day ahead market and the end users. Their main profit is based on the differences between the average spot price and the end user price. The settlement of all contracts is, however, related to the hourly Nord Pool Elspot price. This means that there is always a risk related to unexpected high purchase prices. Most suppliers offer therefore spot price related products to the customers. The last updated overview of end user contract shows in fact a growing share of spot price related contracts (~43 %) while the rest includes Standard Variable Price (SVP) and Fixed Price (FP) contracts (~ 10 %).

Theoretically, the hourly Elspot price is the cheapest alternative for all customers, especially when the potential benefits from load reduction in the high price periods are included. Yet, many customers want to buy fixed price contracts in order to avoid unexpected costs. Retailers selling ordinary fixed price contracts have to take into consideration both the volume and the area price risk. This implies that the fixed price needs to include a risk premium, reflecting the cost for hedging the risk in the Nord Pool financial markets or bilaterally.

An alternative solution is to combine a spot price contract with a financial contract and by that protect the customer from the long time price variations, and at the same time, provide an incentive to reduce consumption in periods of shortage. This is the basis for the new contract “Fixed price With Return option” (FWR) which is offered by the retailer Trondheim Energy. Design, marketing and analyses of customer acceptance and change in consumption for 800 of 2500 customers having this product, has been one of the pilot activities in this project.

[5] Example: The CO_2 emission from a gas fired power plant is 0,5-1 t/MWh

3.2.2 Demand response incentives through the network tariff

The price level in Elspot has historically been relatively flat, and the extreme peak prices are expected to occur seldom. The consequences of a capacity shortage can still be considerable. This is the background for using the network tariff as an extra incentive to change consumption pattern in a way that reduces the peak load, and by that contribute to a socio-economic benefit when shortage occurs. This applies for all hourly metered customers; households, commercials and institutions.

Time of Use (ToU) tariffs have been used in other countries for many years, and price variations over the day, so called Time of Day (ToD) tariffs, is a measure used in parallel with the introduction of Automatic Meter Reading (AMR) and “Smart metering” in e.g. Italy, Ireland and Canada. In some countries, e.g. Finland, time differentiation between day and night in the household tariff has been used in order to move heating of water to the low load periods.

ToD tariffs and spot price energy products have been used in this project both for households and for larger customers. The principles and reason for the choice of tariffs is explained below.

A special allowance from the regulator NVE has been required for the tariffs used in this project (and in previous projects). Note that NVE by the end of the project has stated that *ToD tariffs and other network tariffs that motivate to change of load pattern, will not, at this stage, be allowed on a general basis. This is because of the potential disturbance of the ordinary market mechanisms.*

3.2.2.1 Time of Day (ToD) “energy tariff” for households

ToD tariffs to households are used in two of the pilot activities in this project, ”Remotely controlled load shifting” at Malvik Everk and “Smart house control in housing cooperative” at BKK. The normal “energy” network tariff is transformed by dividing the existing energy part into one part covering the network losses, and one part with high price in the expected peak hours on working days. The high price part is calculated in a way that leaves the “average” customer, who does not change consumption pattern, with the same costs. This means that the responsive customer will reduce the electricity bill.

The choice of ToD tariff is justified by the following arguments:

1. The ToD tariff provides the customer with a reliable price signal that makes investments in e.g. control equipment less risky.
2. Customers who reduce the load in peak hours should be favoured by lower network costs because of reduced need for investments in transmission capacity and lower marginal network losses.
3. ”Energy” based tariff instead of “power based” (see next section) is chosen for households because it gives incentives to load reduction in all of the peak hours and not only in the max hours, which is the case for a power tariff.

3.2.2.2 ToD "power tariff" for commercials and institutions

The power tariffs for commercial customers are traditionally settled on the basis of the peak load of the individual customer, independent on when this peak occurs. The motivation for this tariff has been to cover the costs related to the transmission capacity needed for serving the specific customer.

In this project the focus of the power tariff is changed from the customer peak to *the peak hours of the power system*. This means that only the registered customer peaks in the morning hours and in the afternoon on work days are used for billing.

The main argument for this choice is that it seems unreasonable to "punish" e.g. a baker, who has his peak load when the power system is low loaded, compared to the customers who contribute to the total peak of the system load and by that to increased network losses and need for investments in transmission capacity.

4 REDUCIBLE LOADS

The *low prioritized appliances*, and not the total load, are defined as the *Demand Response Objects* in this project, based on the assumption that there is a limit for what the customers are willing to pay for different uses of electricity.

Some of these appliances, like water heaters and other heating with storage, can be disconnected for a few hours without any discomfort or cost for the customer. These DR objects are suitable for load shifting and have "0" as alternative price in the peak hours.

Electrical heating of water (2-3 kW boilers) is common in Norway and represent ~15 % of the total residential consumption [23], and there is a growing share of electrical heated water borne systems with larger boilers (12-14 kW). A test of the reducible volume represented by household normal water heaters was performed in a previous large scale project involving remote disconnection of water heaters for about 1250 customers [20]. This test showed that the average potential from the water heaters were largest (0,6 kWh/h) in the system peak hour in the morning, (see Figure 4-1). This means that an accumulated load reduction of ~600 MWh/h would occur if half of the Norwegian households switch off their water heater in this hour. This capacity is higher than the output of the largest production unit in Norway.

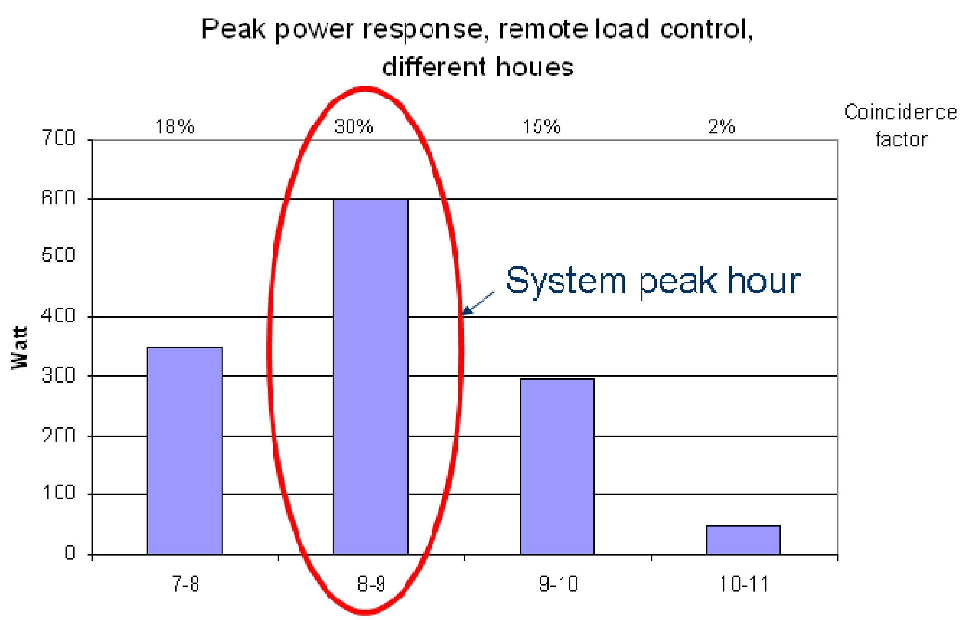

Figure 4-1 DR potential from water heaters in the morning hours

Customer acceptance of load shifting by remote control of water heaters has been among the pilot tests in the Market Based Demand Response project.

Space heating is the other big source of residential consumption in Norway (~60 %). It is therefore natural to focus on switching to other energy sources, e.g. fire wood, in periods (weeks, months) with temporary high price level of electricity (provided that this alternative cost is lower than the cost of electricity).

Use of washing machines, dryers and dish washers are examples of appliances that might be avoided in the peak hours. For commercial customers and institutions reduction of electricity for cooling and ventilation will be additional sources for demand response.

5 IMPACTS OF NEW TECHNOLOGY AND “SMART METERING”

The most important improvements provided by the new metering and load control technology are related to more correct metering, more frequent sampling and the potential of automation of the demand response.

Frequent metering is needed to secure that responsive customers really get lower bills in periods with high prices. Hourly metering of a major part of the load is recommended by this project, and a measure of quality and availability of the data used for settlement is proposed with reference to the requirements of the market.

Surveys show that most customers don’t want to pay attention to hourly market prices. Automatic load control schemes referring to predefined price limits and/or time of day are therefore needed to improve the response. In this project both remote control via AMR and a separate radio based system are demonstrated in some of the pilot activities, and commercial local load control (LLC) options are investigated.

The Norwegian Authorities have now decided that “smart meters” should be installed to all customers in Norway within 2014. This decision implies investments in the order of 4-5 billion NOK. The requirement specification for AMR systems developed in this project together with a group of DSOs, forms a basis for a coordinated and more standardised deployment of the technology. The outcome of the total investment depends, however, on the increased efficiency gained in the meter value chain and on how customers respond to the demand response incentives it provides.

6 PILOT TESTS

WP1 and WP3 in the "Market Based Demand Response" project have included several pilot tests ([1], [2], [3], [14], [16]) involving different project partners. The main objectives of the tests have been to explore the customer acceptance and the load curve impacts on hourly based price signals and automatic load control schemes. The pilots are focusing both on residential and commercial customers. Cost / benefit analyses have not been a part of the studies.

Figure 6-1 shows how the pilots are structured. Each sector represents one pilot, and the name of the company where the pilot has been performed, is presented outside each sector. The inner circle indicates the *customer type*, the circle in the middle indicates the *technology* used in the pilot and the outer circle indicates the *price signal* used. For two pilots the outer circle is divided in two parts because two different price signals were offered to the customers (both a network tariff and a power product).

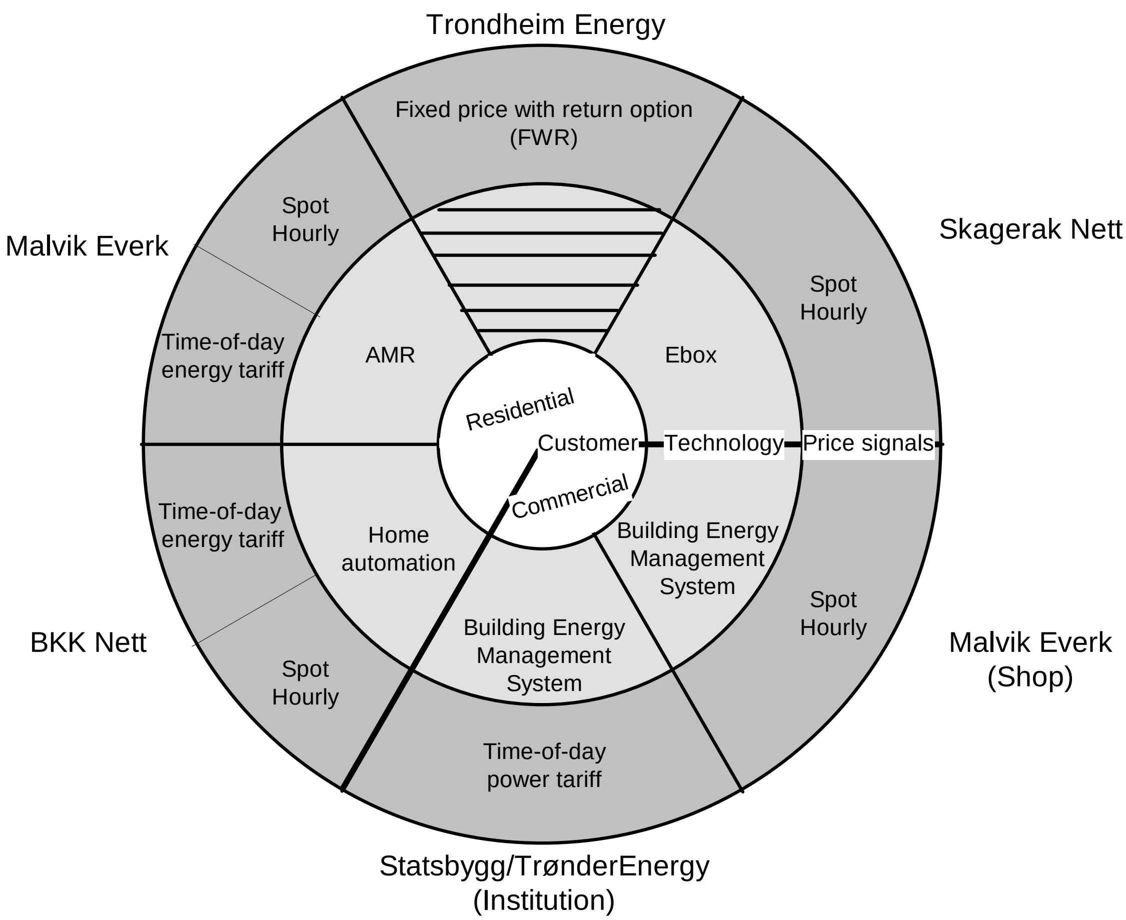

Figure 6-1 Organisation of customer types, technology and price signals in pilots

A summary table of the pilots is presented in chapter 6.6.

6.1 "FIXED PRICE WITH RETURN OPTIONS" ENERGY CONTRACT

The lack of incentive for load reduction in the ordinary Fixed Price (FP) contract was the reason why the Norwegian Parliamentary White Paper (18-03/04) asked for development of new products from the retailers that combines spot and fixed price products. In 2005 the Norwegian retailer Trondheim Energy chose to replace the ordinary FP contract with the contract **F**ixed price **W**ith **R**eturn option (FWR), which meets these requirements. In the FWR product Trondheim Energy offers the residential customers "crude" electricity price (spot price) combined with a price hedge of a predefined yearly fixed volume. Similar products have been common for commercial customers as a part of the portfolio management.

The FWR contract is defined by the local spot price[6], the contract price and the contract volume. The contract volume is divided over the year according to a profile.

The fact that most domestic consumers have limited knowledge of the power markets is a significant challenge related to marketing this type of power products. Trondheim Energy has therefore chosen to market the product as a fixed price and volume product where consumption below the contracted volume is sold back to the market and excess consumption is bought, both at running area spot price level. By illustrating this with a bottle containing a spare volume that is returnable (Figure 6-2), the retailer seems to have succeeded in presenting the product in a way that people understand. The question is whether this way of marketing is acceptable?

Figure 6-2 Bottle to be recycled

Strictly speaking nothing is sold back to the market. The customer pays the area price for the real consumption and achieves a profit or loss in the financial market dependent on the real system price[7].

However, the settlement of a fictitious buy (or sell) back will be similar to the actual settlement, provided that the area and the system prices are equal. Considering the educational challenges related to explaining the product, this choice of marketing is a reasonable trade-off. It is, however, important that the customers are informed about and are aware of the risk aspects related to the potential differences between the area and system prices.

One of the main aspects in WP1 was to study the price responsiveness compared to the alternative products. Figure 6-3 shows the load curve for residential customers having Spot Price (Spot),

[6] The price paid by the customer is the spot price for the area where the power is delivered plus a mark-up for the supplier. The spot contracts to smaller customers are normally priced according to the average area price over the settlement period, while large customers are settled on the basis of hourly prices.

[7] The Nord Pool Elspot "system price" is the price initially calculated with no network constraints taken into consideration.

Standard Variable Price[8] (SVP) and FWR contracts respectively for quarterly periods, each category existing of 800 customers.

The three categories follow each other with exception of the 1. quarter of 2006. The customers with the FWR product reduced their electricity consumption with 24,5 % in 1. quarter of 2006[9], while customers with spot price power products and standard power products increased their consumption with 10,4 % and 7,7 % respectively, in the same period.

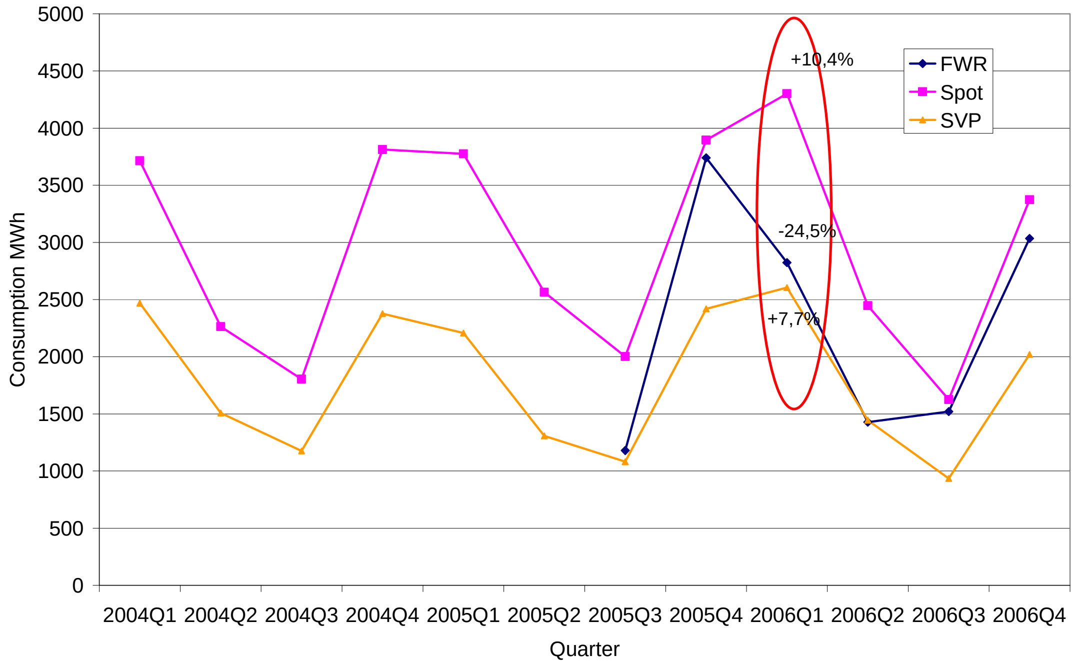

Figure 6-3 Electricity consumption for groups of customers with different power products

The power balance in the Nordic power market was very tight in this period and the spot prices rose significantly. This development of the prices gave the FWR customers a strong incentive to reduce consumption, and the registered response shows very clearly the potential of this type of contract. The customer surveys carried out during and after the test period indicate that a major part of the reduced electricity consumption was substituted by fire wood. Spot price customers did not have the same reaction, although they should have a similar incentive. It is assumed that the reason is the increased awareness of the FWR customers through the marketing campaign that focused on their opportunity to actually make money on the high prices.

The same response was missing in the 3. quarter of 2006 when the spot prices were even higher than in the 1. quarter. A possible explanation is related to the fact that this period was warmer than normal, which led to low consumption and thereby a substantial benefit from the financial contract without additional actions.

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[8] SVP is the default contract for a majority of the retailers. The price may be changed with a two-week's notice, and will normally follow the area price with some delay. Settlement is based on yearly or quarterly "self meter reading" and profiling.

[9] Compared to the consumption in 4. quarter of 2005.

Two questionnaires were answered by a selection of the FWR customers. The main impression from this study is that the customers are focused on own cost savings and follows the power situation through the media. The customer's response to the marketing and the product as such is on the whole positive. There have, however, been some negative comments to the deviations from the fixed price occurring in periods with significant difference between area and system prices.

The project recommends that the contract should be further developed. The supplier should consider taking over the area price risk from the customers, since the supplier has the possibility to reduce his own risk trough proper hedging. Alternatively should the contract be marketed as a combination of a spot price contract and a financial contract with the Nord pool area price and system price as the reference respectively.

6.2 REMOTELY CONTROLLED LOAD SHIFTING

Malvik Everk was chosen to host this pilot because this company is one of few DSOs in Norway with full roll out of AMR to the customers.

40 household customers with hourly metering of their consumption participated in the pilot. The customers were offered a ToD network tariff and they were advised to buy an hourly spot price energy contract.

The ToD tariff stimulated to load shifting, and RLC via the AMR system was offered as an "aid" to reduce load and costs in the peak hours.

The chosen time for the energy peak payment were based on the hours during the morning and afternoon when the peak load for the local DSO occurred. These hours are coinciding with the periods when high spot prices are expected and when the peak load occurs on a national level.

The ToD tariff was based on the traditional energy network tariff and was divided into three parts: Firm, Loss and Energy Peak. The Firm part of the tariff was unchanged 1500 NOK/year (187,5 Euros/year), the loss part was 7,0 øre/kWh (0,875 Eurocents/kWh). The Energy Peak payment was 63,0 øre/kWh (7,88 Eurocents/kWh)[10] and only active 08:00-10:00 in the morning and 17:00-19:00 in the afternoon on work days. The new tariff was calculated in a way that secured that the costs for an "average user", acting as before, was unchanged on a yearly basis. This means that a responsive customer, reducing his load in the predefined hours, would benefit from the tariff and from avoiding the high spot prices that normally appear in the same hours in case of energy shortage.

10 % of the customers had waterborne space heating system with an electrical boiler of 12-15 kW. The rest of the customers had a standard electrical water heater of 2-3 kW.

[10] VAT excluded

The RLC was carried out in the defined high priced peak hours (Figure 6-4), and the customers in the pilot were also equipped with a small watch-like magnetic token, the “El-button” (Illustrated in the upper right corner in the figure). This should be placed on dishwasher, washing machine etc. to remind the households to avoid usage of these energy consuming appliances in the peak hours.

Figure 6-4 Household load curve with RLC - on working days

Registered average demand response in peak load during the morning was approx. 1 kWh/h for customers with electrical water heater and approx. 2,5 kWh/h for customers with waterborne space heating system with electrical boiler. The demand response in this pilot was larger than in previous tests mentioned in chapter 4, (0,6 kWh/h) [20], which indicates that more than just the automatic load reduction via RLC was activated in the peak hours.

Table 6.1 Average demand response

	08:00-10:00	17:00-19:00
Customers with electrical waterborne space heating system	~2,5-3 kWh/h	~1,3 kWh/h
Customers with electrical water heater	~1 kWh/h	~0,5 kWh/h

Figure 6-5 shows the strong relation between the Elspot prices in Mid-Norway and the hours for RLC within the pilot. If this RLC scheme had been implemented in a large scale and included in the Elspot bidding, the price peaks could have been lowered.

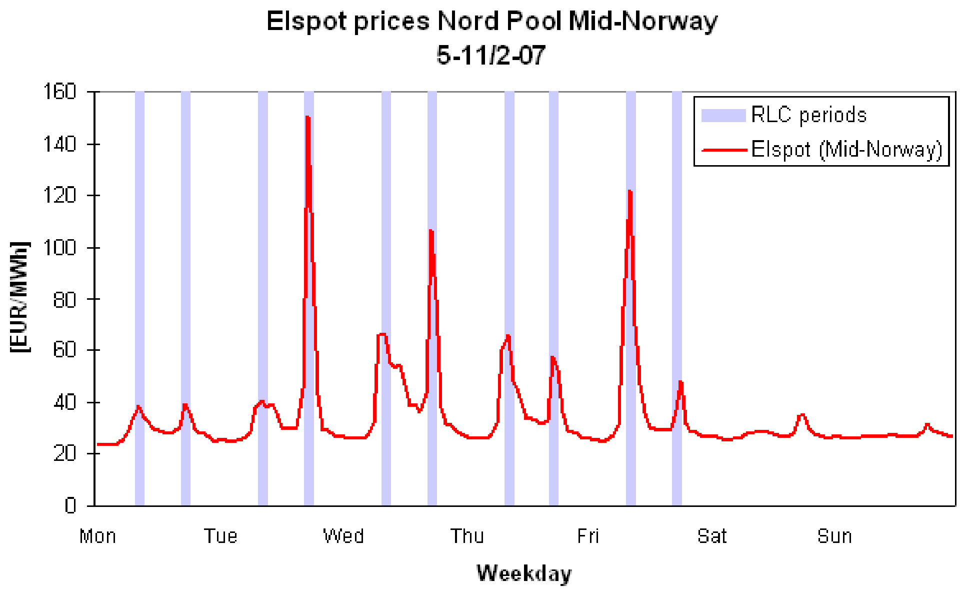

Figure 6-5 Elspot prices Mid-Norway and periods for RLC in the pilot

The remote load control was performed with use of Power Line Carrier (PLC) and relays connected to the communication terminal for the AMR system. Each terminal has three relays, one of 16 A and two of 6 A. The electrical circuit for low-prioritised loads were coupled via the relays of the terminal. Separate contactors are used for loads > 16 A.

The remote load control was carried out as a periodical job performed at predefined hours – directly from substations. The weakness of PLC is failure of the communication when changes in the configuration of the power system are performed and/or when terminals are moved within different substations. Therefore an override switch was installed at each household to reduce the risk for not reconnecting the loads.

During the pilot two questionnaires were answered by the customers (spring 2006 and 2007). The main impression from these is that the customers care about their own electricity consumption, but personal economy has higher focus. The customers accept remote load control, as long as this does not affect the comfort negatively. Several of the customers have adapted the consumption to the new network tariff by manual efforts, by investing in energy control system and/or by buying fire wood for the winter.

6.3 "SMART HOUSE" CONTROL IN HOUSING COOPERATIVE

A cooperative with 24 flats in Bergen, equipped with a programmable home automation system was monitored and analysed. The pilot was performed in 2007. The main aspects of this test were to monitor initiatives taken by the residents with regard to the utilisation of the available technology options, and by that achieving cost reduction.

The local DSO (BKK) offered the customers a ToD tariff based on the same principles as in the pilot presented in chapter 6.2 (in this case with an Energy Peak payment of 0,9 NOK/kWh (~11 €cent/kWh)[11] valid from 07:00 -10:00 and 17:00-20:00 on working days). All customers had hourly metering of their electricity consumption and were advised to have an hourly spot price contract with the supplier

Figure 6-6 "El-button" Sparresgate

To remind the customers of the peak load period, each customer received three magnetic tokens “El-buttons” (See Figure 6-6) (Note that the layout of this button is different from the one used in the Malvik pilot. In this case a 24 hour clock is used. There were, however, no indications with regard to which layout was the best.)

The electricity consumption of the 24 customers was analysed. An average demand profile for working days was calculated for November 2006 (before the tariff was introduced) and February 2007 (after the tariff was introduced) Figure 6-7. The peak load periods are presented in the figure. The calculations are not corrected based on differences in outdoor temperature.

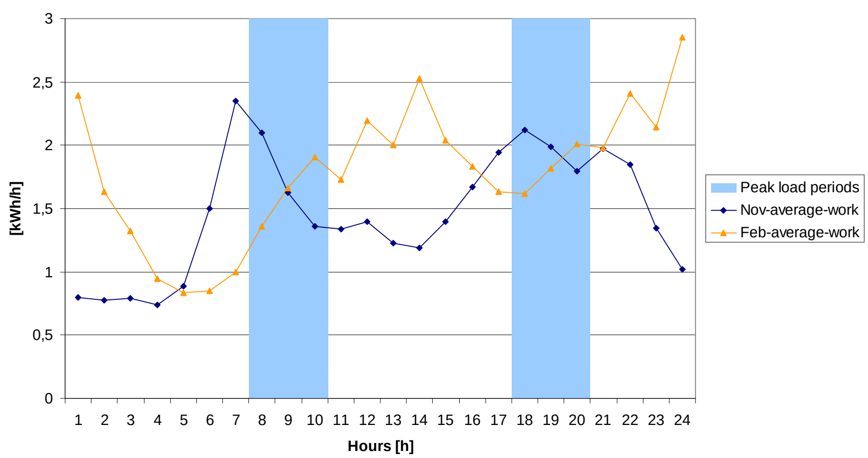

Figure 6-7 Average consumption for all customers (workdays) (Week 47-06, Week 7-07)

The registered changes in consumption pattern in February, compared to November, indicate a demand response based on the new tariff. The customers have shifted loads from the peak load period in the morning to later in the day. In November the peak load was in hour 7, but in February a large part of the consumption is shifted to the hours 12-15. In the afternoon consumption is shifted from peak load periods until later in the evening.

[11] VAT excluded

The feedback given in meetings and in a questionnaire was in general positive. The most used functionality was an “absence-button” which turns all electric appliances into a saving-mode when the people leave the flat.

Different solutions for home automation have been presented during the last years, and this pilot shows that this technology can be used to reduce consumption in peak load periods and also to increase each customers’ knowledge of their own electricity consumption pattern.

6.4 LOW PRIORITIZED LOADS CONTROLLED BY BUILDING ENERGY MANAGEMENT

6.4.1 Institution

The possibility for demand response has been tested in an institution (owned by Statsbygg) with Building Energy Management System (BEMS) installed. In this building only electricity is used for space and water heating. The customer was offered a new ToD network tariff from the local DSO.

This ToD tariff has a part for power peak payment, which implies that only the registered power in defined peak periods (hours 08:00-11:00 and 17:00-20:00 on working days 1. Oct. – 31. March) are included in the settlement basis.

The BEMS is used for load control and for reducing the total consumption by rotating the turning on/off of the different loads. The load control is programmed to minimize the costs, based on the total price signal.

Reducible loads were mapped for the building, and installed power and possible duration of disconnection periods are indicated for each consumption category. See Table 6.2.

Table 6.2 Reducible loads

Load	Duration for period of shortage			
	Hour	Day/ Night	24 hours	Month
Roof heating (16,0 kW)	X	X	X	X
Pavement heating (14,4 kW)	X	X	X	X
Engine heater (20,0 kW)	X	X	X	X
Electrical water heater (for showers) (4 x 15 kW)	X	X		
Electrical water heater (15 kW)	X			
Kitchen (20,0 kW)	X			
Electrical heater cables in the floor in the shower/cloakroom	X	X	X	(X)
Ventilation	X			
Electrical panel heaters (18 zones)	X	(X)		
Indoor swimming pool (60 kW water heater + 60 kW ventilation)	X		X	X

The swimming pool is the largest load in the table, and the loads related to the swimming pool are marked with grey.

The demand response achieved after introducing the new tariff is illustrated in Figure 6-8 and Figure 6-9.

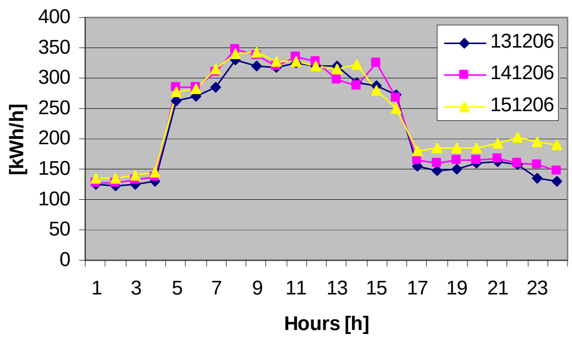

Figure 6-8 Consumption BEFORE introduction of power tariff (13.-15. Dec. 06)

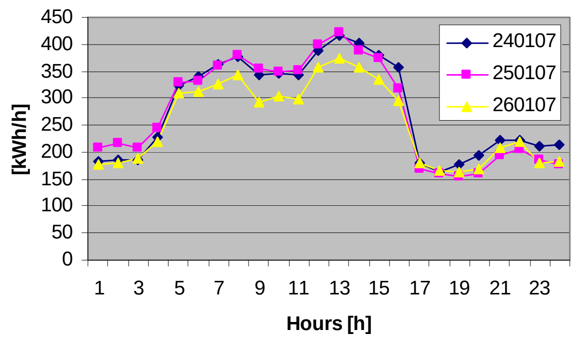

Figure 6-9 Consumption AFTER introduction of power tariff (24.-26. Jan. 07)

A considerable change in the consumption pattern is visible, especially for those hours where the power peak payment was effective. The difference in the level of consumption in the two figures is due to difference in outdoor temperature. The demand response performed with use of BEMS resulted in a reduced consumption in peak load hours of about 50 kWh/h.

6.4.2 Shop

It will always be profitable to reduce the consumption in peak hours, if possible, for customers with hourly metering and hourly settlement of their consumption.

A histogram showing which hours the maximum and minimum spot price occurred in the period from 20 Nov. 2006 to 16 Nov. 2008 is presented Figure 6-10. The maximum price occurred in hour 9 in 140 days, and the minimum price occurred in hour 4 in 264 days. The largest price difference between night and day for the NO2 price area in Norway was 98,34 øre/kWh[12] (12,29 Eurocents/kWh).

[12] In this calculation the hours 7-20 are defined as “day” and the rest of the hours during the day are defined as “night”. The calculation is valid both for working days and weekends.

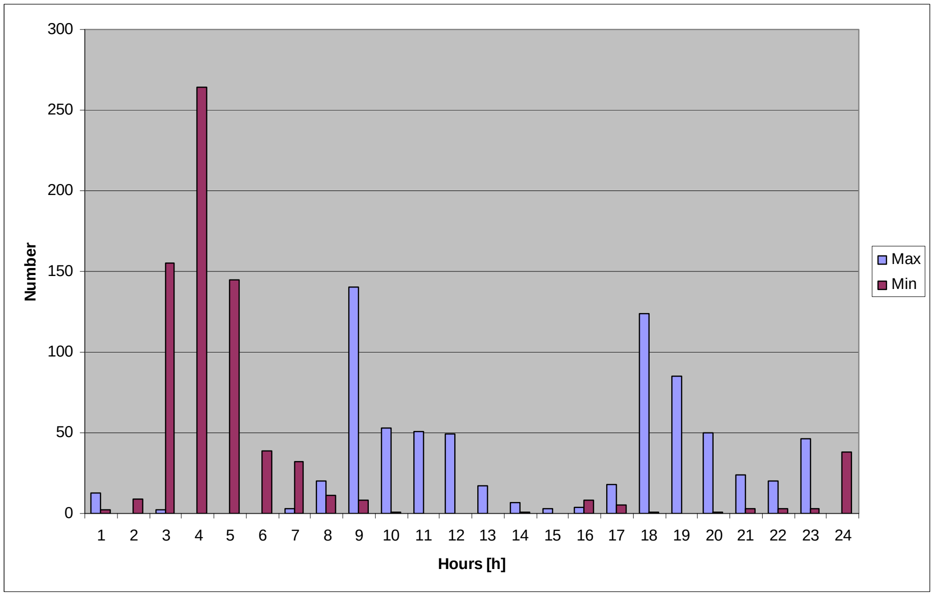

Figure 6-10 Histogram for the maximum and minimum of the spot price during the day (NO2) (Source: NordPool)

The possibility for demand response was tested by a large customer (shop) with hourly spot price settlement. The customer utilized the BEMS to adapt his consumption to the expected spot price variations over the day.

An example of demand response is presented in Figure 6-11. In the 4 last days of week 21 (2008) the appliances for heating were switched on earlier than before, and then switched off when other appliances were started. The heating was on for 05:00-07:30 and 09:45-20:00. (The first day of week 20 was Whit Monday and the shop was closed.)

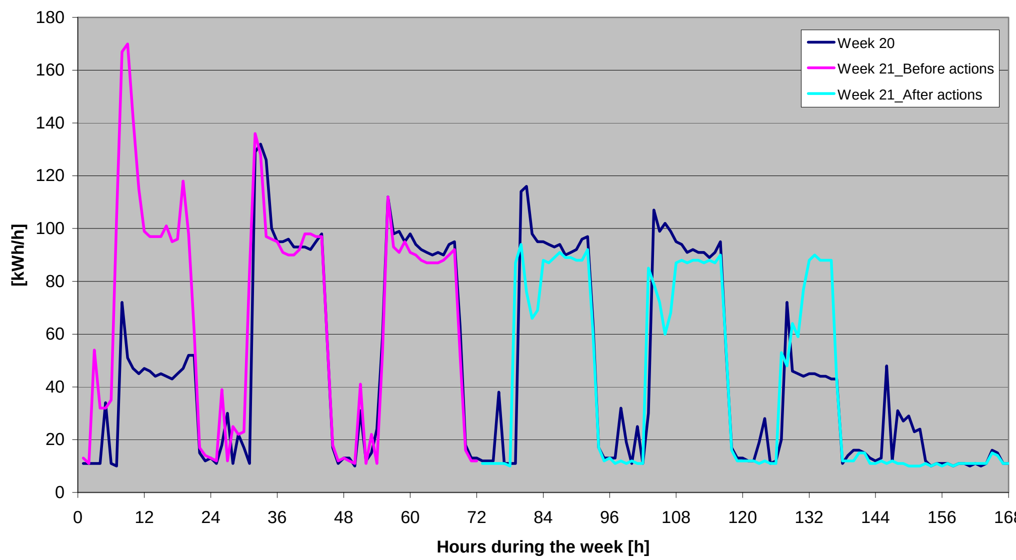

Figure 6-11 Electrical consumption <u>before</u> and <u>after</u> actions for demand response (Week 20 and 21 – 2008)

6.5 AUTOMATIC DEMAND RESPONSE (ADR) REFERRED TO ELECTRICITY SPOT PRICE.

The original objective of this pilot was to establish a concept for automatic reduction of *low prioritized* consumption if and when the spot price exceeds a predefined and contracted price level. The main benefits from this ADR scheme are related to the high price periods and to the fact that most customers are not interested in paying attention to the variations in the spot price from day to day. Due to low and stable spot prices in the test period, the objective was changed to "demonstrate automatic load reduction in *periods with expected high price*".

The demonstrator was based on the functionality of two existing software solution:

- The LeKey for remote load control from APAS[13] (previously Elink AS)
- The Meter Data Management System (MDMS) for documentation and settlement from Powel ASA[14]

Figure 6-12 presents an overview of the interplay between the two systems. LeKey receives the Elspot prices from Nord Pool (Power Exchange) and performs the load control referred to the pre defined parameters and restrictions contracted with the individual customer or customer groups.

The MDMS collects the meter values from the metering system, in this case the AMR system, and processes the data for settlement and billing for all the customers. The customers can be grouped with reference to the suppliers involved, and the customers having load control contracts are treated specially for documentation of the demand response. The red circle indicates the interface between the systems.

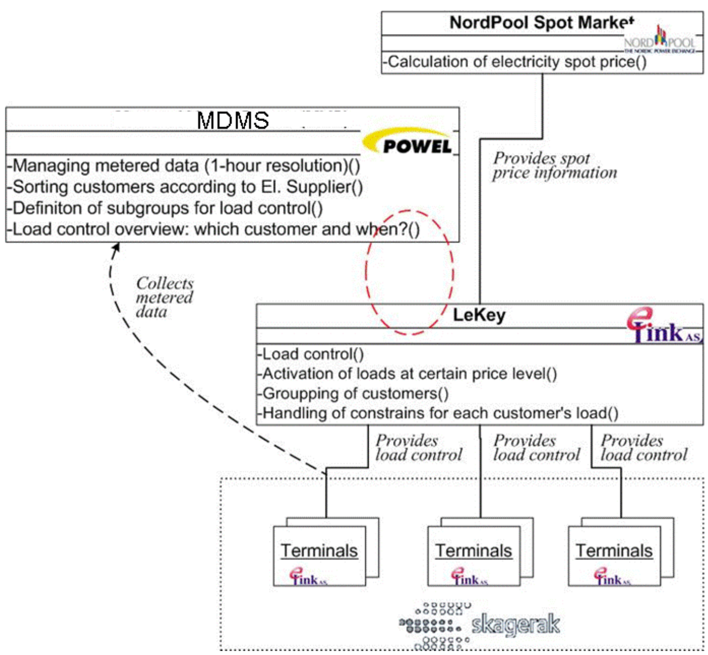

Figure 6-12 Overview of technical solution

[13] http://www.apas.no/
[14] http://www.powel.com/

The pilot was hosted by the DSO Skagerak Nett and performed at residential customers (single houses) with hourly metering of their electricity consumption. All the houses were equipped with an Ebox[15] RLC unit attached to the water heater socket. The Ebox was controlled via radio signals separate from the AMR system.

Several tests were carried out over a period of 2 months. Results from week no. 34/05 (Figure 6-13) are chosen to illustrate the principles. *"The two highest priced hours between 07:00-11:00 and between 16:00-20:00"* was defined as criterion for disconnection of water heaters in this test. The minimum spot price level was set to 100 NOK/MWh. The time for disconnection and reconnection was defined by the hourly spot prices on Nord Pool Elspot as shown in Table 6.3, The yellow hours indicate the timing of the load control.

Table 6.3 Selection of hours for load control referred to Elspot prices [NOK/MWh]

Date \ hour	00-08	07-08	08-09	09-10	10-11	11-16	16-17	17-18	18-19	19-20	20-24
15.06.2005		237,56	244,77	245,76	245,7		232,82	230,87	228,87	228,34	

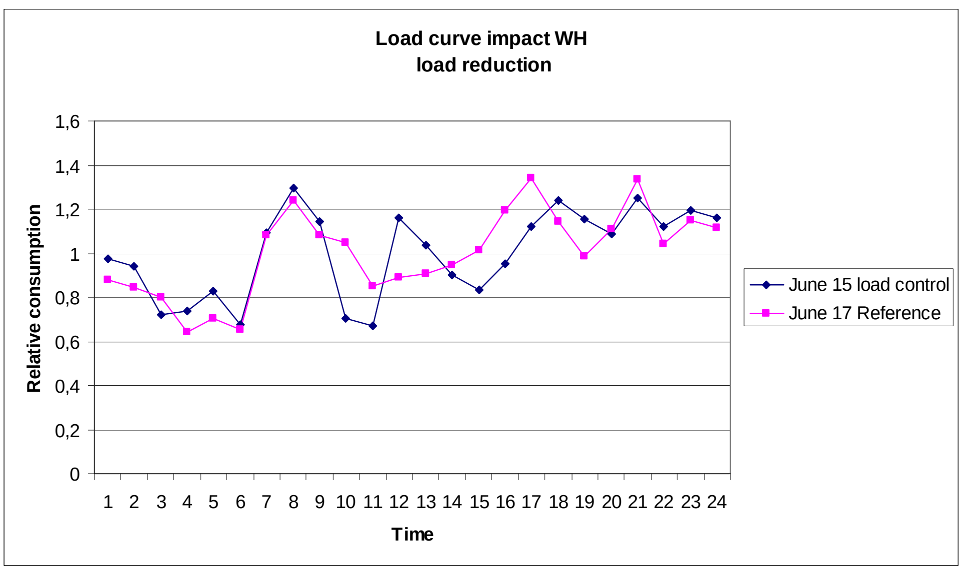

Figure 6-13 Response curve June 15

The curve shows significant response to the activated control in the morning hours. In the afternoon it is more difficult to register the response. The explanation for this difference is probably related to the activity in the households. Several "disturbing" activities like cooking etc. are likely to take place in the afternoon while low activity is normal in the morning hours on working days.

[15] Ebox was developed by the former company Elink and is not a commercial product anymore.

One of the main advantages of ADR with respect to improved market performance is that expected volume of the load reduction at a certain price is known and thereby can be bid into the market.
Both the power supplier and the DSO are involved with the customers when offering power contracts, network tariffs and RLC. A general arrangement concerning contracts and Elspot bidding can be as follows (see Figure 6-14):

- The power suppliers enter into a contract concerning volume and price for reducible load, with customers that have hourly metering and RLC. For practical reasons it is expected that only a few spot price levels for disconnection would be offered, both to limit the contract variety for the power supplier and to ease the alternatives for the customer.
- The power supplier and the DSO have to make an agreement concerning the RLC.
- The power supplier includes the price/volume information from the RLC contract in the Elspot bids.
- The DSO receives information of the spot prices the day ahead and plans and performs the load disconnections.

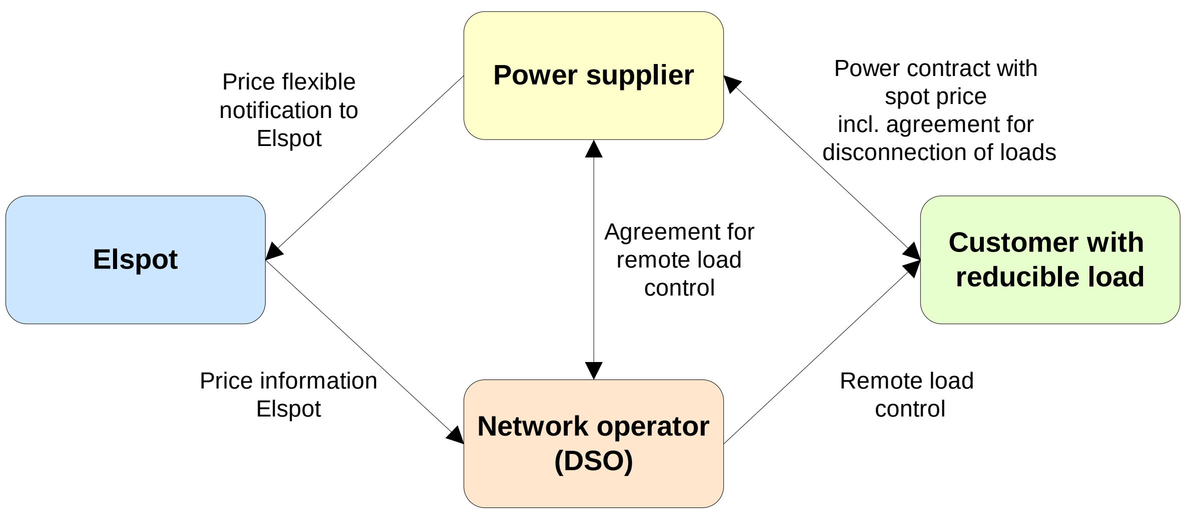

Figure 6-14 Contractual and technical arrangements

6.6 SUMMARY OF PILOTS

Pilots	Customer type	Price signal	Technology		Other initiative towards customer	Demand Response
			Load control	Metering		
“Fixed price with return option”	Household	Spot price	-	Self-reading quarterly	Web page for the power product	Reduced energy consumption by 24,5 % in 1. Quarter of 2006 (referred to 4. Quarter 2005).
Remotely controlled load shifting	Household	Time-of-day energy tariff. Hourly spot price	Remote load control via AMR. 2 hours during morning and afternoon.	Hourly metering of total el. consumption (AMR)	“El-button”. Consumption information via web page.	Reduced consumption in peak load of 1 kWh/h for customers with ordinary water heater and 2,5 kWh/h for customer with waterborne heating system.
“Smart house” control in housing cooperative	Household	Time-of-day energy tariff	Home automation.	Hourly metering of total el. consumption (AMR)	“El-button” (24h)	Reduced consumption in defined peak hours.
Low prioritized loads controlled by BEMS	Office building	Time-of-day power tariff	Building energy management system	Hourly metering of total el. consumption (AMR)	-	Reduced consumption in defined peak hours of about 50 kWh/h.
	Shop	Hourly spot price	Building energy management system	Hourly metering of total el. consumption (AMR)	-	Reduced load in expected peak load periods.
Automatic Demand Response (ADR)	Household	Hourly spot price	Remote load control via Ebox in the two hours with highest spot price during 07:00-10:00 and 16:00-20:00.	Hourly metering of total el. consumption (AMR)	-	Considerable response during the morning. Less response during the afternoon.

7 IMPROVEMENT OF TECHNOLOGY

The objective of WP2 has been to contribute to improvements of quality and efficiency in the meter value chain and to promote technology that makes demand response feasible. In this report the results from the following main activities are summed up:

- Assessment for the quality and availability of meter data [6][17]
- Survey of experiences from DSOs that have performed full-scale deployment of AMR [8]
- Development of a requirement specification for full-scale implementation of AMR in Norway [9]
- Establishment of the Nordic AMR-forum

The DSOs are, according to the regulations, responsible for the collection and the quality assurance of metering information. Consequently, the DSOs are responsible for the establishment of AMR systems. Norwegian regulations require presently hourly metering of all customers with a yearly consumption above 100 000 kWh. In the proposition document (NVE autumn 2008) [26], frequent (probably hourly) metering of the electricity consumption for all customers in Norway will be required within 01.01.2014.

Description of the meter value chain

The meter value chain includes a complicated infrastructure required for registration, transfer and management of metered data. A typical example of the chain at Norwegian DSOs is presented in Figure 7-1.

Initially, electricity consumption is registered by a Meter. The registered data is stored in the Meter Terminal and periodically transferred by using various types of Communication to the Central System (Data Collection System, also called Front-end System). The data is further transferred to Related Systems like the Metered Value Database (MVDB) for quality assurance process and to the Customer Information System (CIS) for billing.

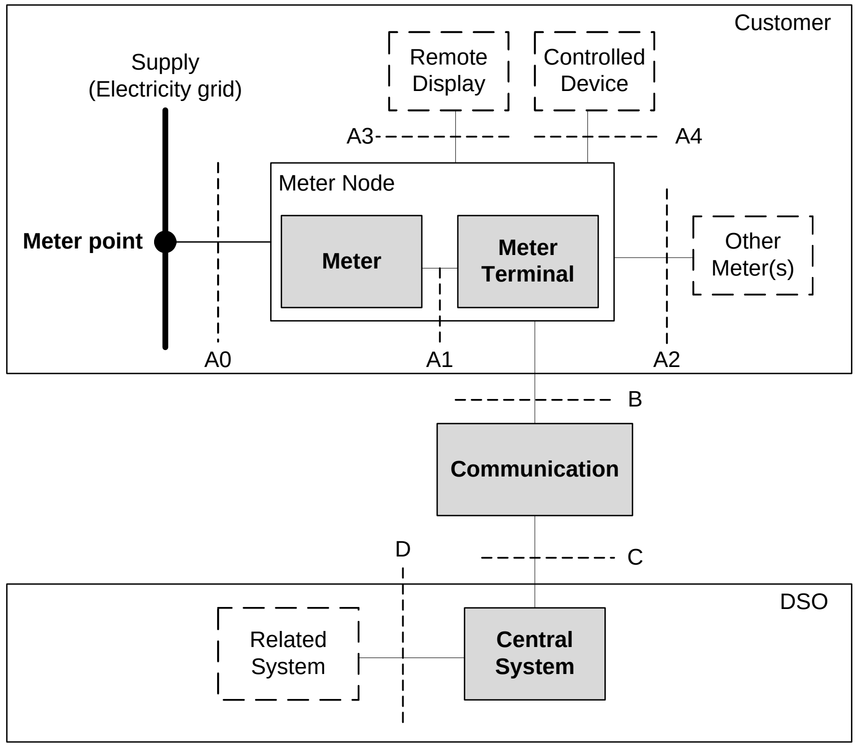

Figure 7-1 Meter value chain

7.1 QUALITY AND AVAILABILITY OF METER VALUES

Today there is no universal, clear and quantifiable definition of metering quality, which should be provided by AMR systems. The electricity metering itself e.g. registration of consumed electricity by the primary meter is clearly regulated on national and European levels. These requirements, however, are not applicable to the rest of the meter value chain from the meter's external interface to the data storage (-s), which is used for billing the customer. The experience shows that considerable errors and/or data losses occur during transfer of metered data from the terminal to the data collection system. Defining the metering quality is beneficial for several market actors:

- It allows Authorities to set concrete and clearly quantifiable requirements to the whole metering value chain.
- It assists DSOs in development of technical requirements for purchasing of AMR equipment, its installation and commissioning in order to ensure that performance of the equipment corresponds to the technical requirements.
- It contributes to overall improvement of billing and settlements procedures, ensuring that the customers are billed correctly.

Defining the metering quality

The experiences from tests and analyses in this project show that it is necessary to differentiate between requirements for metering quality and availability of metered data.

The proposed definition of metering quality consists of the two following parts:

(I) **Metering quality** is defined as 100 % minus the percentual deviation between the metered **energy volume** and the actual energy volume within the customer's settlement period.

(II) **Availability of metered data** is defined as the percentual number of error-free **metered values** within the customer's settlement period. This means that missing and erroneous values, deviating from the true values at the given metering point, are excluded. The metering availability for a group of customers over a period of one week (168 hours) is:

$$T = \left(\frac{UKM}{TKM * 168} 100\% \right)$$

Where:

T – *Metering availability*
UKM – *Total number of metered error-free values (excepting estimated values), which are available per week*
TKM – *Total number of metered customers for the given week*

The metering quality relates to the traditional legal requirements to the metering instruments based on metered energy volumes. On the other hand, the metering availability definition relates directly to AMR systems and therefore is easier to identify. Error of a metered electricity volume depends also upon availability of metered data, but the function will additionally include several other parameters. For example, the customers, having direct electric heating, will consume much more electricity during winter time. The missing and erroneous values during the winter time will therefore cause much higher error in the registered electricity volume, compared to the same missing or erroneous values during the summer.

Experiences from monitoring the availability of metered data from 17.000 customers
The availability of meter data from six different DSOs in Norway was analysed. Three of the DSOs have more than 60 thousand customers, two companies have 15 thousand of customers and the last one has less than 15 thousand customers. It was identified two different clusters of customers:

- 8647 hourly metered customers with yearly consumption over 100.000 kWh.
- 9180 hourly metered customers with yearly consumption below 100.000 kW.

The analysis was based on collection of metered data from week 1 to week 40 in 2006. The participating DSOs submitted the metered data weekly to SINTEF Energy Research and the data were analysed by using an appropriate software tool (Useload[16]). The metered data was automatically collected every week by the DSO. However, sometimes several reading and transfer attempts were necessary to get the data. Estimated data was not included. The analysis of the availability covered only missing data, not erroneous data. However, experiences show that missing data is probably a much larger problem that erroneous meter values.

[16] "Useload" is a computer tool developed at SINTEF Energy Research. The tool is designed for segmenting metered time series into different end-uses and to predict peak demand.

Table 7.1 summarizes the assessment of availability of metered data for two groups of customers.

Table 7.1 Estimated availability of metered data

DSO nr	Without estimated values Average (week)	Share of error-free customers
Customers with annual consumption over 100.000 kWh		
1	99.17	86.25
2	99.96	99.90
3	99.03	86.00
6	99.92	97.80
Average	**99.52**	**92.49**
Weighted average:	**99.64**	**94.54**
Customers with annual consumption less than 100.000 kWh		
1	92.25	49.29 *)
2	99.92	98.85
3	99.13	87.44
4	97.02	2.56 *)
6	99.98	98.90
Average	**97.66**	**67.41**
Weighted Average:	**97.52**	**82.70**

*) The low values were caused by lost PLC communication due to changes in network configuration.

Since the number of customers is different at these DSOs, the study has also calculated average weighted percentages for availability of metered data on weekly basis and number of error-free customers. All the DSOs use combination of PLC (high voltage) and GSM (from different vendors) for transfer of the metered data.

Having errors (because of missing meter values) in metered data may have very different consequences dependent of the customer type, energy contract and distribution network tariffs. The consequences can be fairly insignificant for household customers with fixed electricity price, but crucial for industrial customers paying network tariffs with max capacity charge.

Therefore, Norwegian DSOs will spend more efforts to collect the real data from the large customers than from the smaller. This is probably one of the main reasons for the difference in availability for metered data from large (99.52%) and small customers (97.52%). Another reason is that so far hourly metering of small customers has mainly been used in test projects with reduced emphasis on the quality in the meter value chain.

The large scale analysis of availability of metered data showed a possibility for at least 99 % in average over a 26 weeks period. 99% availability should therefore be considered included as an overall requirement, especially for larger customers.

7.2 EXPERIENCES FROM FULL-SCALE IMPLEMENTATION OF AMR

This description of experiences from full-scale establishment and operation of AMR at three Norwegian and three Swedish DSOs is based on information gathered in meetings with the DSOs during 2007 and 2008.

Table 7.2 The DSOs included in the description

Country	DSO	Total number of customers	Status for customers with AMR
Norway	No1	12.800	100 % (2007)
	No2	16.000	88 % (Aug. 2007)
	No3	5.500	100 % (2003)
Sweden	Se1	100.000	100 % (Before Jan. 2009)
	Se2	25.000	100 % (1997)
	Se3	850.000	100 % (June 2009)

The three Norwegian DSOs are small companies with 5.500 – 16.000 customers. The Swedish DSOs are very different with respect to the number of customers, where they are in the process for establishment of AMR and the degree of cooperation with other DSOs.

Knowledge of others experiences are important for Norwegian DSOs that will establish AMR in full-scale. Differences between Norway and Sweden related to installation and management can, however, make it difficult to use the Swedish experiences directly. One important difference is that most of the meters in Sweden are installed outside the house, while the meters in Norway normally are installed inside.

Some of the experiences are:

- **Establishment**
  - The cost for full-scale implementation of AMR per metering point is varying from 1300 to 2000 SEK/NOK with the majority close to 2000. These costs are supposed to cover "everything" (like meters, installation, project management, etc). The numbers must be considered as indications of the costs.
  - For most of the DSOs the installation has mainly followed their originally plan, and it has been sufficient to visit the customer once.
  - The customers have been pleased to get AMR.
  - It has been hard to get in contact with the last percents of the customers. Especially in areas with a lot of holiday cottages or with many non-native-speaking customers there have been problems.
  - Cooperation between 30 DSOs in Sweden (SAMS) gave power in the negotiation with the vendors. The number of hours spent in the tender-phase was reduced compared to the expected time each DSO would have used if they had worked separately. However, the period used increased.

  - The products SAMS wanted to buy were not available. It took about 2 ½ year from new functionality was specified until it was available in the products.
  - It is a great advantage with IT-based support tools in the installation process.
  - No1 had very good experiences with using own employees for installation in the evenings and being pay per metering point.

- **Management**
  - Several of the DSOs receive in average more than 99 % of the meter values they try to collect. This is also the result for a DSO which is collecting hourly values every day from all its customers. DSOs with a lot of holiday-houses in its concession area are receiving approximately 97 % of the values. It is hard to discover the difference between missing values and installations which are turned off and therefore not sending meter values.
  - The meter values seem to be correct. It is very seldom discovered error in the received values.
  - Se2 that established AMR based on PLC already in 1997, was satisfied with the technology the first years. However, after some years there arose several serious and new problems with the communication technology.
  - Several of the DSO have experienced that meter terminals dies after a period. Then it is necessary to visit the customer and install a new terminal. It is important to cover such a situation in the contract with the AMR vendor.

- **Reduced costs from more correct metering**
  - Full-scale implementation of AMR and replacement of old meters result in a more correct metering, which contribute to a reduction of the “un-metered” part that previously was included in the cost category concerning “network losses”.
  - A more correct metering in full scale provides updated information concerning the consumption in the distribution network, and reduces the uncertainty with regard to network expansions.

- **Demand Response**
  - Se2 has introduced power tariffs to all their customers, and the peak load was reduced with 2% due to this. The tariff gives the customers incentives to reduce the peak load. However, Se2 has not registered any reduction in energy consumption related to full-scale employment of AMR.
  - No3 established load management at 40 customers in a pilot test. The test has been included as a pilot in this project and the results are presented in chapter 6.2.

7.3 REQUIREMENT SPECIFICATION

Requirement specification concerning full-scale implementation of AMR has been developed[17] in a working group with among others representatives from 7 larger Norwegian DSOs.

The objective of this work has been to develop specifications that Norwegian DSOs can use when implementing AMR in full-scale. If several (or hopefully all) DSOs use this specification in their tenders and negotiations towards the vendors, this will contribute to a certain degree of standardisation of the AMR technology. The specification has focused on functional requirements.

The final requirements from the Regulator (NVE) are expected in the course of 2009. These requirements are basic for the specification developed in this project. However, the specification contains additional aspects regarding among others metering, quality of supply and value added services.

The requirement specification covers the following topics:

- Functional requirements
  - Metering
  - Power Quality
  - Network operation
  - Value added services
- Technical requirements
  - Requirements concerning meter and metering points
- Requirements concerning installation
  - Physical requirements in the metering point
  - Information handling during the installation
- System requirements
  - System stability and lifetime
  - Response time
  - Response rate
  - Standardisation of interfaces
  - Central system (Front End)
  - User-friendliness
  - Interaction with other software systems
  - Security in information handling and registration of consumption
  - Dimensioning and upgradeability
- Requirements for cost-effective management and maintenance

The main requirements related to demand response are:

Requirement	Category
Hourly metering (registration in the meter every 60 min)	Required from day one
Remote load control of loads	Optional
Transmission of information to local unit at the customer site	Required from day one
Connection of supplementary equipments in the Metering point	Optional

[17] The documentation will be finished when the final requirements from the authorities is available.

Examples of other basic requirements:

The transferred data should be the meter value visible on the meter and not based on pulses. Using the meter values instead of the pulses increases the quality of the information used for billing purposes. If some information is missing and it is necessary to estimate the consumption, it is possible to get a much better estimation by using the differences between available meter values (real values for the period with missing values) than by using old “pulse”- information from similar periods.

The interfaces between different parts in the system should be open and documented. An AMR-system consists of several parts, and in most cases it is necessary for the DSO to buy all the parts from one single vendor. The interfaces between the different parts of the system are in most cases vendor-dependent. It has not been possible so far to establish standards for the interfaces. Further, it will not be possible to establish standards before the AMR technology is going to be rolled out in Norway. The situation makes the DSO dependent of the AMR- vendor and investing in a full-scale system may be a huge risk. By requiring opened and documented interfaces the risk is to some degree reduced. Then it will be possible for vendors to implement parts of other vendors systems. Further, if interfaces are available, it may lead to a development towards standardisation, because it is less use for a vendor to develop an interface if is already developed and tested by another vendor.

The metering should be performed in all 4 quadrants (consumption, production, active and reactive power).
If all the DSOs in Norway require the possibility for metering in all 4 quadrants, the meters will not cost more than “ordinary” meters (because of the production volume). The possibility of metering in all 4 quadrants is future-oriented because of the potential for more local production than today. Further, local production and also new types of loads probably increase the need for monitoring reactive power in the future.

7.4 ESTABLISHMENT OF THE NORDIC AMR-FORUM

SINTEF Energy Research, VTT (Finland), Elforsk (Sweden) and DEFU (Denmark) initiated in 2006 a pre-project in order to organize a Nordic AMR Forum. Nordic Energy Research has supported this initiative, and resources from the Marked Based Demand Response project has been allocated for the pre-project.

The pre-project has focused on mandate, organisation and financing of a potential permanent forum. A preliminary group of members from the utilities and technology vendors from the Nordic countries has been established, and two workshops with 50-60 participants have been arranged. The pre-project ended at the end of 2008.

The Steering Group for the pre- project recommends establishment of a permanent Nordic AMR-forum from 2009 with the following objectives:

- Contribute to harmonisation of the technical rules and regulations related to implementation and operation of AMR systems
- Develop of a common strategy, related to use of data formats (protocols) for transfer of metered data
- Share experience among Distribution System Operators, related to implementation and operation of AMR systems
- Work on functional requirements for AMR systems (as well as minimum requirements) in order to fulfil the future needs of metering and Demand Response.

For further information: http://www.sintef.no/Projectweb/AMRforum

8 CONCLUSIONS AND RECOMMENDATIONS

The main conclusions and recommendations from the Market Based Demand Response project are summarized in the following bullet points:

- Temporary reduction in space heating and load shifting of water heaters are the most convenient demand response objects in Norway
- Frequent metering is needed to secure that the responsive customers really get lower bills in periods with high prices
- ToD network tariff combined with hourly spot price provide the customer with a *dynamic price signal that gives incentives to needed investments and to load reduction in peak hours*
- “System peak” should replace “customer peak” as reference for settlement of power network tariffs
- Spot price combined with fixed price should be standard contracts for all customers
- Remote control via AMR systems is an alternative to local control systems
- Automatic Demand Response (ADR) schemes should be further developed
- Rational implementation of remote and/or local control options should be considered as a part of the coming AMR projects.
- Quality requirements should be included in the directions from the regulator
- The requirement specification developed in the project is recommended as a basis for tenders.
- Nordic cooperation in the Nordic AMR Forum should be prioritised
- The investments in AMR systems need to be followed up by dedicated programs with focus on how to respond to price variations, preferably combined with information about the environmental impact (CO_2 emissions etc.)

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APPENDIX 1 TERMINOLOGY

ADR	-	Automatic Demand Response
AMR	-	Automatic Meter Reading
BEMS	-	Building Energy Management System
CIS	-	Customer Information System
DR	-	Demand Response
DRR	-	Demand Response Resources
DSO	-	Distribution System Operator
Elspot	-	24 hour day ahead market operated by Nord Pool
FP	-	Fixed Price
FWR	-	Fixed price With Return option
LLC	-	Local Load Control
MDMS	-	Meter Data Management System
NOK	-	Norwegian Krone
NVE	-	The Norwegian Water Resources and Energy Directorate
PLC	-	Power Line Carrier
RLC	-	Remote Load Control
RPM	-	Regulation Power Market
SEK	-	Swedish Krone
SVP	-	Standard Variable Price
ToD	-	Time-of-Day
ToU	-	Time-of-Use
TSO	-	Transmission System Operator
VAT	-	Value Added Tax
WP	-	Work Package

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