E F F L O C O M

Energy efficiency and load curve impacts of commercial development in competitive markets

EU/SAVE 132/2001

Incentives for Demand Response and for Investments in Infrastructure and Technology

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Summary

This report is the second part of the documentation from phase 3 of the EFFLOCOM project, which analyses the impacts of new communication infrastructure on energy consumption.

The main focuses of this report are the incentives the customers are facing with regard to demand response, and the incentives different parties have to invest in needed technology. The final cost-benefit analyses for the specific investment/effort are decisive for the realism of the projects in question. A general discussion of the principles and main aspects of the costs and benefits and potential ways of co-funding of the infrastructure is included in the report.

A lot of customers in the electricity markets pay a retail price that is average over time, despite the fact that the electricity markets refer to a spot market, which is traded on an hourly basis. These customers have no incentive to respond by load reduction on high prices in the shortage periods, e.g. in the morning and the afternoon hours. This lack of price sensitivity on the demand side leads to market inefficiency and in the long run significant advantages for the producers who can decide the price in the peaking hours.

The goal is to improve the demand side price elasticity on general basis, and the demand response in case of shortage. It is assumed that the most important incentives for load reduction are related to money and profit. The network tariffs and the energy price are of this reason important factors for the response. An overview of the different price signals the customer is facing in the participating countries is presented and discussed on a more general basis.

In a deregulated environment the electricity price paid by the customers consists of the following elements:

- Network tariff (from the network owner)
- Energy price (from the supplier)
- Taxes (from the authorities)

France has just started its deregulation process while the Nordic countries have several years of experience. The electricity price to customer has of this reason not reached the same level of “unbundling” in France as in the other countries participating in the project. The main difference is that the energy price is confidential in France while it is public in the other countries.

The main customer incentives for load reduction are related to the price signals given by the network tariff and the energy price. Experiences from the EFFLOCOM project and previous studies indicate that the following tariffs and energy products give the best motivation for load reduction:

<u>Network tariffs</u>:

- Time of Use (ToU)-tariffs with inter day variations in price
- Dynamic tariffs that are amplified in periods with shortage

<u>Energy Price</u>:

- Hourly spot price
- Hourly spot price combined with automatic load reduction when the spot price is high
- ToU-price e.g. with day /night variation

The taxes represent in most cases a major share of the electricity bill and will, if the tax is a fixed price independent of the consumption, represent a limitation of the potential price variations provided by the network tariffs and energy prices mentioned above.

A bilateral contract for load reduction is an alternative to price elasticity efforts. Most of the schemes implemented relate to system operator products for reserves and reliability purposes. The Nordic TSOs have all utilized interruptible or reducible loads as capacity reserves. Mainly larger industrial loads are used, but aggregated minor loads are also an option.

Common for the price signals mentioned above is the need for reliable documentation and to some extent controllability of the loads in question. This means that more frequent metering and facilitation of load control (LC) are required for the consumption in question.

In most cases these requirements lead to the conclusion that investments in technology for automated meter reading (AMR) are needed.

The most common way of executing AMR is to replace the conventional meters with electronic devices and to establish Direct Communication (also called Two Way Communication) between customer and the company responsible for the metering. This technology, which is described in a separate EFFLOCOM report [2], includes the option of remote control of reducible loads.

However, the whole meter value chain has to be improved to secure that the quality of the metered values are good enough for the power market. This means that supplementary investments in Customer Information Systems (CIS) and/or Meter Value DataBase (MVDB) have to be expected. Utilization of the Internet and investments in web-based services is another object of interest.

There are several motivations for investments in the technology mentioned. Some of the motives are based on the interest of the whole society to the benefit for all, and some are related to the benefits of each actor involved. Basically the benefits could be categorized in the following groups:

A. Improved end user response to shortage in production and/or transmission capacity
B. Efficiency improvements with regard to metering and data management procedures
C. Improved quality and precision of metered data
D. Profit and cost savings

The benefits of the stakeholders are mixed together and full benefit is in many cases dependent on investments by several parties. The different aspects with regard to investments in needed technology is discussed, referred to the stakeholders: Society, Transmission System Operator, Market Operator, Network Owner, Supplier, Customer and other energy service providers.

One important aspect when considering introducing some kind of varying electricity prices is the outcome of the cost-benefit analysis of the experiment.

The analyses of the experiments have usually showed a lack of welfare justification because the costs of the equipment needed for hourly metering of the energy consumption exceeds the benefits. However, with new technology, the costs might become lower than the benefits. Regulations and/or dedicated subsidies from the authorities might be needed if the net corporate benefit remains negative, provided a positive socio-economic outcome of the investment.

The cost/benefit aspects for investments in different technologies are discussed separately based on the methodology described in the “Guidebook for B/C Evaluation of DSM and Energy Efficiency

Service Programs" prepared for the European Commission in 1996, and on the description of the different actors interest for investments.

So far investments in technology have been limited of economical reasons because the different actors does not find profitability alone. More cooperation between the stakeholders and regulatory arrangement are needed to secure that projects that are proven socio-economic beneficial will be accomplished.

In general stable regulations and tax policies from the authorities are needed to reduce the regulatory risk of investments.

1 Introduction

Automated Meter Reading and Load Control via Direct Communication to the customers facilitates a whole range of new customer services. Not only can customers continuously receive and react manually or automatically to the prices in the market, but hourly metering information can be used to tailor-make energy efficiency services best fit the customer in question.

Phase 3 of the EFFLOCOM project analyses the impacts of new communication infrastructure on energy consumption. The questions are whether the electricity customers react on varying prices, and whether the costs of implementing new meters and equipment can be justified with regard to the cost/benefit calculation.

The focuses of this report are the incentives the customers are facing with regard to load reduction, and the incentives different parties have to invest in needed technology. The final cost-benefit analyses for the specific investment/effort are decisive for the realism of the projects in question. A general discussion of the principles and main aspects of the costs and benefits and potential ways of co funding of the infrastructure is included in the report.

The EFFLOCOM pilots referred to in the report are listed in Table 1.1.

Table 1.1 EFFLOCOM pilots.

Pilot no.	Country	Title
I	Denmark	Hourly metering with two-way communication and web-based interface for customer control and monitoring the consumption
II	Finland	Effect of web-based feedback on the electricity consumption and load curves
III	France	Tempo tariff feedback at EDF
IV	Norway	Implementation of Demand Side Management in Oslo
V	Norway	New technology for controlling of Power load in Oslo
VI	Norway	Consumer flexibility by efficient use of ICT

2 Incentives for load reduction

A lot of customers in the electricity markets pay a retail price that is average over time, despite the fact that the electricity markets refer to a spot market, which is traded on an hourly basis. These customers have no incentive to respond by load reduction on high prices in the shortage periods, e.g. in the morning and the afternoon hours. This lack of price sensitivity on the demand side leads to market inefficiency and in the long run significant advantages for the producers who can decide the price in the peaking hours.

The goal is to improve the demand side price elasticity on general basis, and the demand response in case of shortage. It is assumed that the most important incentives for load reduction are related to money and profit. The network tariffs and the energy price are of this reason important factors for the response.

"Price signals" are partly covered in EFFLOCOM report no. 2. "Phase 2 Influence of Competition on load curves" [1]. This chapter gives an overview of the different price signals the customer is facing in the participating countries. The tariffs, the energy products and the influence of taxes are described and discussed on a more general basis.

2.1 Overview price signals used in participating countries

In a deregulated environment the electricity price paid by the customers consists of the following elements:

- Network tariff (from the network owner)
- Energy price (from the supplier)
- Taxes (from the authorities)

France has just started its deregulation process while the Nordic countries have several years of experience. The electricity price to customer has of this reason not reached the same level of "unbundling" in France as in the other countries participating in the project.
The price elements above are divided into the following subgroups:

Network tariff:	Standard, Time of Use (ToU) and Dynamic.
Energy price:	Firm, ToU and spot price products (spot)
Taxes:	Electricity tax/fee, Value Added Tax (VAT)

2.1.1 Finland

Table 2.1 Price signals Finland..

Main elements	Sub Groups	Comments
Network tariffs	Standard Demand tariffs ToU	MWh + fixed charge MWh / MW + fixed charge Day/night/ weekend + seasonal + interruptible
Energy Price	Firm ToU Spot + marginal	Normally on yearly basis (small customers without heating) Electrically heated houses, service and industrial customers Industry customers, households, smaller industry and commercials
Tax	Electricity tax VAT	Two classes: Households, industry 22 %

2.1.2 Denmark

Table 2.2 Price signals Denmark.

Main elements	Sub Groups	Comments
Network tariffs	Standard ToU	MWh / MW Season + hours per day (Three levels)
Energy Price	Firm “Floating”/variable Spot (hourly) Average spot	Flat tariff in some cases with maximum limit Most common tariff for households Industry customers (+households in test projects) Households, smaller industry and commercials
Tax	Electricity tax VAT	Energy, CO_2 and PSO (larger for household where all taxes together constitute around 60 % of the payment), energy efficiency fees 25 %

2.1.3 France

Table 2.3 Price signals France for eligible customers.

Main elements	Sub groups	Comments
Network tariffs according to voltage	High voltage: U>50kV: - Single price linked to subscribed power and annual load factor	The network tariff depends on: - supply voltage - power subscribed (only for mass market customers). The network tariff is the same all over France and does not take into account the distance ("post stamp" principle). No dynamic tariff for network
	Medium voltage: 1kV<U<=50kV: - Single price linked to subscribed power and annual load factor - ToU (5 or 8 time periods) only in case of seasonal uses and low load factor	
	Low voltage: U<1kV: - Single price linked to subscribed power - ToU (2 time periods in a day defined by the local distribution network responsible)	
Energy price	CONFIDENTIAL Some kind of real time tariff is proposed to some eligible customers	Before 1 July 2004 only big customers (annual electricity consumption> 7GWH) were eligible and their tariff is confidential. All professional customers are going to become eligible from 01 July 2004, but their tariff has not been communicated yet. For mass market customer, dynamic tariff could be justified in the near future according to the evolution of generation capacity.
Taxes	VAT Local taxes	19,6% (VAT=5,5% only in case of voltage <36kVA and for a part of the bill depending on the subscribed power) About 10% (different according to town and region)

2.1.4 Norway

Table 2.4 Price signals Norway.

Main elements	Sub Groups	Comments
Network tariffs	Standard ToU Dynamic	MWh / MW + interruptible Season (+ hourly in test projects) In test projects only
Energy Price	Firm "Floating" / variable Spot (hourly) Avarage spot	Normally on yearly basis Most common for households Industry customers (+ households in test projects) Households, smaller industry and commercials
Tax	Electricity tax VAT	0.095 NOK/MWh 24 %

2.2 Network tariffs

2.2.1 Standard

The standard tariffs represent a variety of tariffs offered to the consumers. These tariffs comprises one or more of the following elements:

- Fixed part (price per customer per year)
- Power part (price per kW per year) (Generally used for industrial customers with automated meter reading.)
- Fuse based part (fixed part depends on the size of the connecting fuses: 3 x 25 A, 3 x 35 A, 3 X 63 A etc)
- Energy part (price per kWh)

The main categories of "standard" tariffs are described below.

<u>Energy tariffs</u>
The energy tariff used in Norway, Finland and Denmark contains the fixed part and energy part and is principally offered to household customer, weekend cottages and smaller industrial customers without hourly metering.

The fixed part represents the customer costs per year for the network operator. In Finland it depends on the size of the connecting fuse. The energy part is a price per kWh consumed electricity.

Energy tariff = Fixed part (price/year) + Energy part (price/kWh)

The standard energy tariff gives no incentive for demand response (load reduction).

<u>Power tariffs</u>
The power tariff is offered to industrial customers with hourly metering of the electricity consumption.

The power tariff contains a fixed part, an energy part and a power part based on the power consumption for the customer in defined periods.

Power tariff = Fixed part (price/year) + Energy part (price/kWh) + Power part (price/kW)

Customers with a power tariff can also get a time differentiated energy part such as the household customers.

The price per kW in the power part can be dependent on the consumption for the customers. As an example there can be one price per kW for a peak load up to 50 kW and another price per kW for a higher peak load.

The electricity consumption is metered more frequently than for customers with energy tariffs. The most common is hourly metering of the consumption. The meter data is the basis for different alternatives for calculating the power costs:

- Using the meter data to find the hour with highest consumption in a specific period (a year, a month etc.)
- Using the meter data to find the three hours with highest consumption in a specific period and using the average of these values when calculating power costs.
- Using the average of the two highest 15 minute power during the high load season (common in Finland)

By using the average value of several peak load hours, the customer gets an incentive for reducing his consumption even after he has got an hour with large consumption. When reducing the consumption, he will lower the average value. If the actual consumption is used, the customer has no incentives for reducing the consumption after an hour with large consumption.

A power tariff can for example be on a monthly, seasonal or yearly basis.

Fuse based tariffs
Fuse based tariff is used to increase the fixed charge as a function of the size of connecting cable. Fixed charge increase when the size of the connecting fuses increase. No separate peak power measurement is needed.

Interruptible tariffs
The previous described tariffs are offered to electricity consumption defined as prioritised. There is also developed interruptible tariffs for consumption defined as electricity consumption without priority.

The main thought behind this tariff is that the customers get a discount on the tariff, if the customer has electrical loads that can be disconnected in periods with scarcity of power or energy.

Interruptible tariffs can contain a fixed part, an energy part and a power part. The power part is only offered to customers with hourly (or more frequent meter reading) or a maximum demand indicator. Other customers do only get the fixed and energy part. The energy part in the interruptible tariffs can be time differentiated.

The discount in the tariff is dependent on how long time it takes to disconnect loads and how long the loads can be disconnected. For electrical boilers with oil-fired backup there is no limit on the duration of the disconnection, but the disconnection needs to be notified 12 hours before. For electrical water heaters the duration of disconnection is limited, but the load can be disconnected instantaneously.

The discount in the tariff will increase when the warning time for disconnection is decreased. Additionally increased duration of the disconnection will increase the discount.

Alternatives for the duration from the notice of disconnection is given to the disconnection is performed are:

- Instantaneous disconnection (remote control)
- 1 hour time of warning
- 2 hours time of warning
- 12 hours time of warning

2.2.2 Time of Use (ToU)

To increase the incentives to load reduction in stressed periods the variations in the actual electricity price should be conveyed to consumers in the form of time varying rates. Different variable pricing schemes, static or dynamic, can be used for this purpose. Static time varying prices, generally called Time-of-Use (ToU) or Time-of-Day (ToD) prices are preset for pre-determined hours and days. These variable rates will then become a way for the electric power industry to provide a better match between the price the residential consumers pay for their electricity and the time varying marginal costs of providing this commodity. The intent behind these rates is that if customers pay more for energy during peak times, and less during off-peak times, they will have an incentive to shift their energy use away from the peak periods.

The benefits that might be expected from such tariffs are several: Information about costs is more accurately signalled to consumers, and where substitution possibilities exist, consumers are provided with an incentive to avoid consumption during peak periods. This allows utilities to flatten their system load shapes, decrease their system peaks, pay less for energy supply than they would without the variable rate, and reduce the need for costly capital investment. When the utility pays less for its energy supply this saving will in turn be passed on to the customers.

Example of ToU tariffs used in Norway

In general all the Norwegian customers are offered a seasonal differentiated energy tariff. The seasonal tariff contains a fixed part for covering customer costs. The energy part differs with a higher energy price per kWh consumed electricity during the winter than during the summer.

Two different ToU tariffs are used in Pilot VI. The household customers get a ToU tariff with an energy part and the industrial customers get a ToU tariff with a power part.

The energy and power part is only activated in periods defined as peak load hours. The fundamental principle of the tariffs is that the costs for using the distribution network should be considerable higher in peak load periods.

The time variable energy part is activated in periods from November to March, on workdays in the hours 8-11 and 17-20 (0700-1100 and 1600-2000). This is illustrated in Figure 2.1 and Figure 2.2.

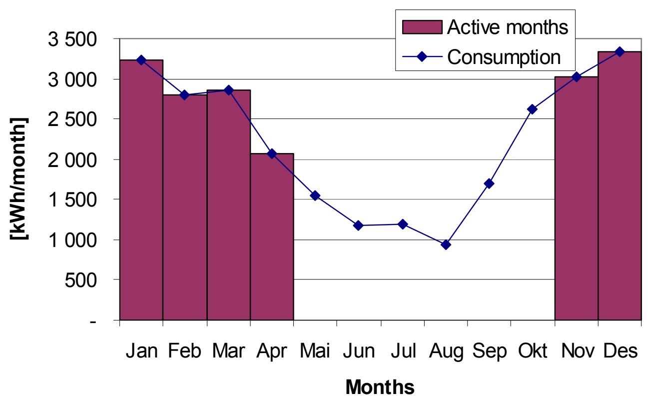


Figure 2.1 Months defined as peak load.

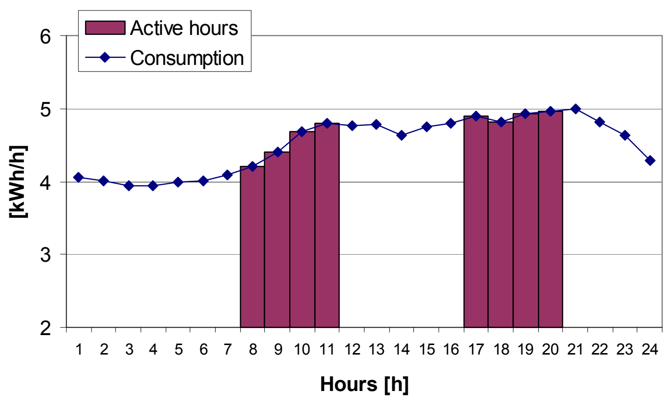


Figure 2.2 Hours defined as peak load.

The average consumption of the three peak load hours during a month is used as reference for the power tariff. When using the average consumption instead of the actual consumption, the customer still has an incentive for reducing the consumption after one hour with high consumption.

Example ToU tariff Finland

In Finland, ToU tariffs are commonly used for electrically heated houses and for commercial/industrial customers. They were used already before the deregulation, and in current competitive situation both the network operators and the suppliers use them.

Usually there are 2, 3 or 4 different time zones with different prices. The variation between different companies is large both in defined time zones and price variations.

In a typical 2 time zone case there are different price for daytime (07 – 22) and night time. Quite often whole Sunday or whole weekend is low-priced.

In a typical 4 time zone case the day/night price varies also seasonally so that during winter time (typically from the beginning of November to the end of March) the price level in both day and night time is higher than in summer time (rest of the year).

In a typical 3 time zone case the price during summer time is flat but during the winter time there is difference between day and night price.

As a result of this pricing, almost all electrically heated houses have heat storage for hot water heating (typically 300 litres), and hot water is produced during night time. Also electrical floor heating using the storage capacity of the floor is commonly used meaning that day time consumption in these kinds of houses is typically 20…30 % from the whole electricity consumption. The next figure shows the typical load curve of the electrically heated house.

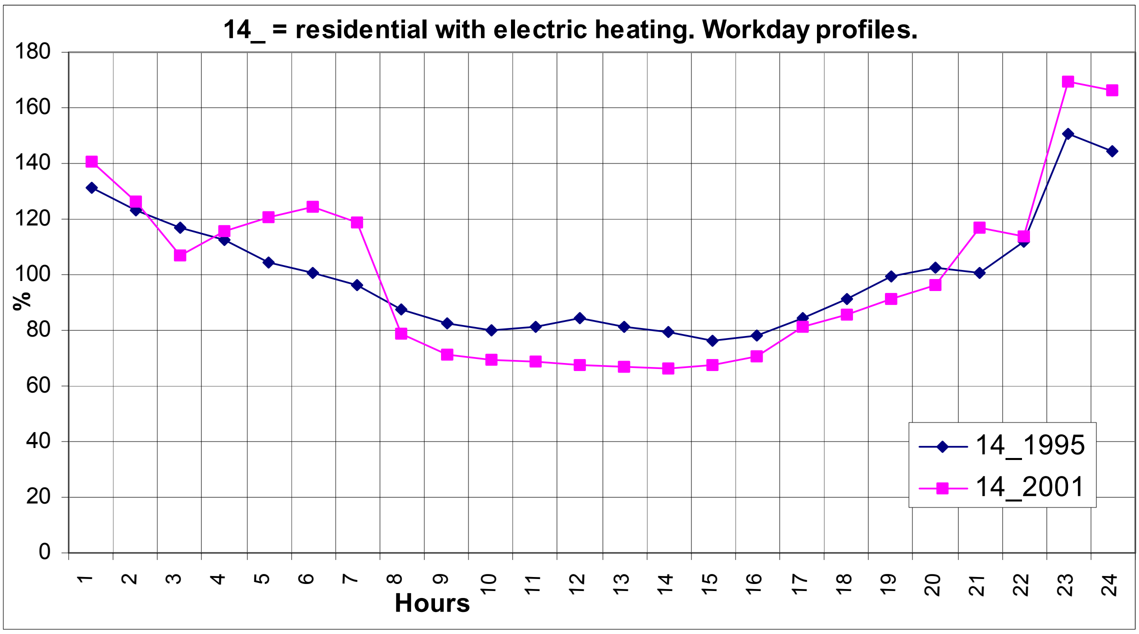


Figure 2.3 Typical load curve of the electrically heated house (1995 and 2001).

2.2.3 Dynamic

Dynamic and real-time rates have won acceptance in electric utilities during the last years. Rather than having fixed prices during peak and off-peak periods, these rates are posted much closer to the time of consumption.

There are few examples of pure dynamic network tariffs. The main reason for using dynamic network tariffs is related to capacity problems in the grid.

Examples of dynamic network pricing Norway:
In the Norwegian pilot VI dynamic tariffs were evaluated, but these are not included in the practical test. Two versions of dynamic network tariffs were discussed:

- Temperature dependant ToU tariff
  A temperature dependant ToU tariff was offered to household customers connected to Buskerud Kraftnett. The tariff was dependent on the outdoor temperature. The tariff was based on the ToU Energy tariff presented in chapter 2.2.2, but the energy part was only activated when the outdoor temperature at the main office for the company was lower than –8 °C.

  The temperature dependant ToU tariff was initially introduced to customers in the city Drammen in 2003. The network tariff was not included in the large-scale test, because when the network tariff should be offered to other customers in other areas, it was a problem to give a reasonable temperature reference for the tariff.

- Network tariff with spot price related pricing (also called real time pricing)

  A network tariff with spot price related pricing was introduced to 21 household customers in Norway. All household customers had hourly metering of their electricity consumption.
  The structure of the network tariff was:

  $$\textit{Network tariff}_{spot} = \textit{Fixed part} + \textit{Spot price amplification} * \textit{Spot price} * \textit{Consumption}$$

  The fixed part represented customer related costs, and the spot price part on an hourly basis represented an amplification of the spot price.

  The network tariff with spot price related pricing was not included in the large-scale test in the pilot VI due to the Norwegian Regulator's objections for including the spot price in the network tariff in this way. The regulations require that the network tariffs should represent the network costs only.

2.3 Energy price

2.3.1 Firm price products

The firm price product guarantees an offered fixed price for the whole period, normally one year, but also seasonal products are available. The customer pays an extra overhead added to the supplier's price forecast and gets a product without risk.

This product puts in other words all the risk on the supplier who in cases of extreme shortage might loose a lot of money, dependent of the contracted volume. The risk comprises both volume and price uncertainty. The risk can be reduced considerably by bilateral contracts with producers or by price hedging in the financial markets like the Nord Pool Future and Forward Markets.

The firm price gives the customers no incentive for load shaving or peak load response. But of course in periods with long lasting energy shortage the price level might be so high that the customer chooses to use other energy sources.

Special contracts with customers who are willing to reduce load in case of unexpected high prices in the spot market is an interesting option for volume risk reduction. In the Norwegian pilot VI this idea was developed as a potential for customers with remote control of low priority parts of their load via direct communication. The idea is that the obtained reduced risk for the supplier should make it possible to offer these customers a lower firm price.

2.3.2 Variable price

Variable price products are normally firm price with a shorter horizon and with a potential of changing the rate on short notice. This product transfers more risk to the customer because the supplier can change the price when the trend and forecasts change. The possibility for the customers of changing supplier damps the temptation of claiming unreasonable high prices.

These products give the customer no incentive for load shaving or peak load response, but to some extent to lower consumption in energy shortage periods.

2.3.3 Spot price products

Hourly spot
Spot or real time price can only be offered to customers with hourly metering. These are straightforward products where the supplier leaves all the risk to the customer by letting him pay the market price for every hour. The supplier profit from the products comes from the overhead, which tend to be lowered by the competition between the suppliers.

In a well functioning market the spot price is the lowest price in the long run. That is one of the reasons why this product is so popular. The customers will gain in all the low price hours and will have the opportunity to reduce costs in peak hours by systematic load reduction when prices are high. In pilot VI and somehow pilot I the customers were offered a combined spot price and load reduction product, where a predefined spot price limit is the criteria for automatic load reduction.

Average spot
This is an alternative for customers without hourly metering. The average spot price for the metering interval is used for the accounting.

Hourly spot price is the best product for improvement of price elasticity.

2.3.4 ToU energy tariffs

In Finland ToU energy tariffs are commonly used as explained in 2.2.2

2.4 Taxes

In some cases taxes represent the major share of the electricity bill, without having any function as and incentive for load management.

Different alternatives for taxes are:

- A fixed price independent of the electricity consumption
- A consumption tax with a price per kWh consumed electricity
- A percentual mark-up on the total costs for electricity

If the tax is a fixed price a customer has to pay – independent of the electricity consumption, the tax will not give any incentives for the customer to reduce the consumption. To reduce consumption, the customer needs to see positive results from their effort for demand response.

A tax as an additional price per kWh will result in increased total price for electricity, and can give the same incentives for reducing consumption as increased electricity prices. The same will be valid for a tax as a percentual mark-up of the electricity costs.

A tax that will increase if the consumption exceeds a predefined limit, can result in positive incentives for reducing the electricity consumption.

2.5 Bilateral contracts for demand reponse/ load reduction

There will always be a discussion of whether bilateral contracts with larger reducible loads might be a better alternative for demand response than mass marked options involving all the costs for infrastructure and information about price signals. So far most of the schemes implemented involve some kind of payment for the willingness of load reduction. There are some examples of such payment to minor customers, especially in test projects e.g. in pilot V and VI, but most of these schemes are System Operator products for reserves and reliability purposes.

In the EFFLOCOM project the following contracts are used (table 2.5):

Pilot	Contracted volume	Payment	Comment
V	~1 MW /customer	~NOK 150 / kW	Included in the power part of the network tariff (50 % reduction)
VI	~2 kW (water heater)	~NOK 700 / year	Firm payment / tariff reduction

Table 2.5 Contracts / agreements used in EFFLOCOM pilots.

The Nordic TSOs Fingrid (Finland), Svenska Kraftnät (Sweden) Statnett (Norway), have all utilized interruptible or reducible loads as capacity reserves in case of capacity shortage [3].

Svenska Kraftnät has entered into contracts with larger end users who are obliged to bid into the day-ahead market and/or the balancing market. The price for this commitment is ~SEK 20000 / MW / Month.

Fingrid is purchasing reserves from larger industrial consumers, mainly as disturbance reserves. This reducible capacity is also available in the balancing market.

Statnett has from the winter 2001/02 invited both producers and larger end users (> 25 MW) to bid into their new Regulation Capacity Option Market (RCOM). This market was established to ensure that there are sufficient reserves in the Balancing Market (Regulating Power Market). The demand side share of this market has in some periods exceeded 70 %, which makes this market a successful example of utilisation of reducible loads in power system operation. The price in the RCOM market has typically been 600 – 1900 Euro /MW /month. It is important to notice that this payment is for standby reserves. When the reserves are activated e.g. in the Balancing Market, the price of the balancing market will give an additional credit.

Oct. 2003, the Danish TSO Elkraft System invited customers with backup generation power units or interruptible loads to bid into their new Regulation Capacity Option Market (RCOM). Elkraft System is now about to sign 18 contracts covering 40 units and 32 MW including 29,7 MW standby power (13 contracts) and 2,3 MW interruptible power (5 contracts). The payment is in average below 27000 Euro/MW/year. The use of this capacity is expected to be 10-30 hours per year. The other Danish TSO, ELTRA, has June 2004 made a contract with the Norwegian company EffektPartner who offered to make contracts with customers with backup generation power to be used as operating reserve. Effektpartner will establish the communication structure and the contract period is one year.

Similar contracts are also applied in France, but the content of these contracts is confidential.

3 *Incentives and framework for establishment of needed technology and infrastructure*

The description of price signals in the previous chapter indicates that ToU and real time pricing from the network owner and from the supplier of energy are the most effective with regard to demand responsiveness. Use of bilateral contracts for load reduction is an alternative or supplementary approach. However, common for these approaches are the need for reliable documentation and to some extent controllability of the loads in question. This means that more frequent metering and facilitation of load control (LC) are required for the consumption in question.

In most cases these requirements lead to the conclusion that investments in technology for automated meter reading (AMR) are needed.

The most common way of executing AMR is to replace the conventional meters with electronic devices and to establish Direct Communication (also called Two Way Communication) between customer and the company responsible for the metering. This technology, which is described in a separate EFFLOCOM report [2], includes the option of remote control of reducible loads.

However, the whole meter value chain has to be improved to secure that the quality of the metered values are good enough for the power market. This means that supplementary investments in Customer Information Systems (CIS) and/or Meter Value DataBase (MVDB) have to be expected.

Utilization of the Internet and investments in web-based services is another object of interest.

These technologies (see figure 3.1) are briefly described in this chapter as an introduction to a discussion of the different actor's interest in investing in the different parts.

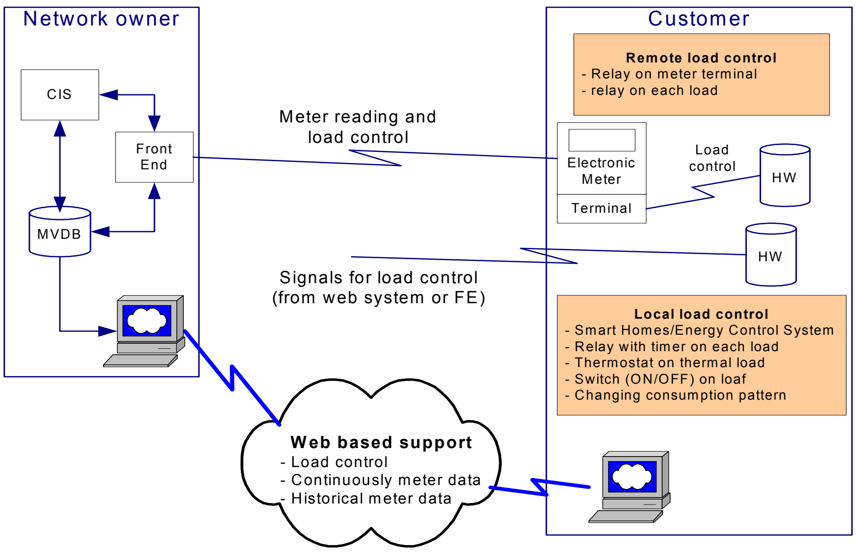


Figure 3.1 Overview of technology options for AMR, RLC and web based support.

3.1 ICT options

3.1.1 AMR

The technology for automated meter reading (AMR) involves new electronic meters and Direct Communication. The different services that can be developed, are dependent on the sampling frequency for the system, meaning how often the consumption is metered.

The metering is normally based on one of the following principles:

A. Continuous sampling of consumption (pulse counting)
B. Reading of the accumulated consumption

The complexity (and cost) of the AMR scheme is to some extent dependent on the time resolution requirement (metering category in brackets):

- Metering every 15. minutes (A)
- Metering every 30. minutes (A)
- Hourly metering (A and B)
- Daily metering (B)
- Monthly metering (B)

3.1.2 Load control

The technology for load control can be divided in to main categories: Remote and local load control. The category for *remote load control* is when an external operator can perform the connection/disconnection of loads at the site of the customer. The category concerning *local load control* is when the customer himself is taking initiative to investing in technology and performing the load control.

Different alternatives are presented for each category.

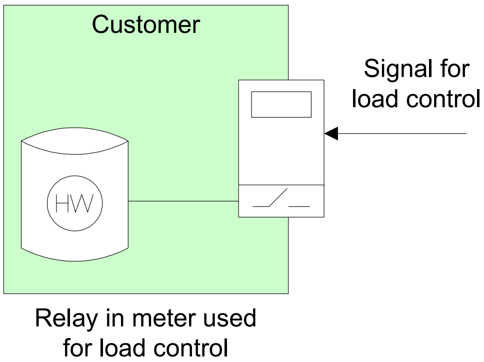
Remote load control (RLC)

- Relay connected to the meter terminal
  A relay is connected to the meter and the system for automated meter reading is also used for load control. The utility that is responsible for the automated meter reading, will also be responsible and performing the load control.

  The relay in the terminal will be connected to an electric circuit in the fuse terminal box. The whole electric circuit will be disconnected, and it is therefore important that there is no appliances on this circuit that should not be disconnected.

- Relay connected directly to the load
  A relay is connected directly to the load. This relay can for example be installed between the outlet and the plug of the specific appliance. This technology does not disconnect the whole electric circuit, but only the specific load.

  The communication to the relay installed at the specific load can receive radio signal for connection/ disconnection of the load.



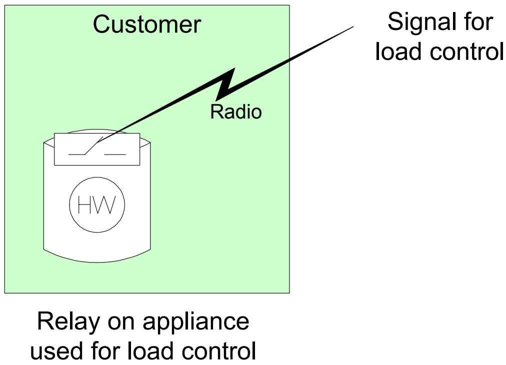


Figure 3.2 Different alternatives for remote load control.

Local load control (LLC)

- Energy control system/Smart Home
  This is a complete control system installed in the house/building, with the possibility for controlling different appliances in the house. The different appliances can be turned on/off at specified times, the room temperature can be lowered in periods when the house is empty (or during the night) or appliances can be disconnected if the spot price exceeds a predefined limit. It is the customer that performs the programming of the load control, but the programming can be based on incentives for reducing electricity consumption in periods with high prices.

  The energy control system gives the possibility for automating routines such as lowering/ increasing the temperature dependent on the presence of residents.

  An energy control system has a central unit from where all the programming/load control will be performed. A relay is installed at each appliance that should be controlled, and the communication between the central unit and each appliance can be preformed with use of radio, Power line carrier (PLC) or specific communications network.

- Relay with timer installed at a specific load
  This is a simplified version of the energy control system, where the central unit and the relay are included in the same box. A relay with the possibility for programming when the appliance should be connected/disconnected is installed directly to the specific appliance.

- Thermostat on thermal loads
  A thermostat installed at thermal loads will make the loads to work towards a predefined temperature. A thermal load without a thermostat will use the same electricity all the time, while a thermal load **with** a thermostat will be turned on and off to maintain the specific temperature in the room or in the water (dependent on the type of load). A thermostat on a thermal load will result in reduced electricity consumption compared to a thermal load without a thermostat.

- Switch
  A switch on an appliance will give the customer the possibility to turn the load on and off. The consumption pattern of this load will depend on which incentives the customer has to reduce the consumption.

- Changing the consumption patterns
  Changing the consumption patterns is a possibility to reduce or change the electricity consumption without any new technology installed. This is a change in the habit of the residents, and is very dependent on which incentives the customers get to reduce their daily routines.

3.1.3 Meter Value and Customer Systems

Front End System (FE)
The Front End System is the final part of the system for automated meter reading. The Front End system is installed at the utility that is responsible for the meter reading, and collects meter data from the terminals/concentrators installed in the distribution network.

The Front End System is usually delivered by the same vendor that has delivered the terminals and concentrators for meter reading.

Meter Value Data Base (MVDB)
The Meter Value Data Base is the main storage of meter data. The information is transferred from the Front End System to the MVDB. In addition to storing data, routines for quality assurance of the metered data can also be performed by the MVDB.

Customer Information System (CIS)
The Customer Information System contains information about the different customers in the concession area. The CIS gets information from the Front End, about the electricity consumption for each customer. The CIS can also get meter data from the MVDB.

The CIS is used for settlement and invoicing of the electricity consumption for the different customers.

3.1.4 Web based support

Different systems have different possibility for web based support for both the owner of the system, and the customer (user). Different examples and which actors that can be interested in this functionality are presented below.

- Load control via web
  Remote control of loads can be performed from a web interface. The possible loads that can be disconnected will then be presented via a web interface.

  A utility or the TSO can use this functionality for remote control of several loads. A customer can use this functionality for controlling the different appliances at home.

- Meter data via web – continuously
  The meter data for the electricity consumption can be presented via a web page. With continuously updating of the data, a network operator can use this functionality to get information about the consumption in the area/network.

- Historical meter data via web
  Historical meter data can be presented via a web page. The historical data should not be too old, because then the information will have no value for the utility or the customer. A customer can for example every week/day get information about their electricity consumption the previous week/day.

3.2 Interest from the involved actors

There are several motivations for investments in the technology mentioned in the previous section. Some of the motives are based on the interest of the whole society to the benefit for all, and some are related to the benefits of each actor involved. Basically the benefits could be categorized in the following groups:

A. Savings (spot and regulation reserve) by improved end user response to shortage in production and/or transmission capacity
B. Efficiency improvements with regard to metering and data management procedures
C. Improved quality and precision of metered data
D. Profit and cost savings

The benefits of the stakeholders are mixed together and full benefit is in many cases dependent on investments by several parties.

With this background the following aspects could be listed for the different stakeholders with regard to investments in needed technology.

3.2.1 Society

Demand response to high prices and reduced consumption in general will reduce the need for new production and power lines, which in the long run will improve the environmental qualities of the society. The main aspect from the authority point of view is therefore to encourage needed investments by regulations and arrangements. Hourly metering requirement is an example of such regulations.

The framework stated by the authorities is in other words basic for the investments that each single actor cannot defend.

3.2.2 Transmission System Operator and Market Operator

These two actors have a specific responsibility to secure the power system operation and to promote a more efficient power market. Improved market performance through more demand side responsiveness is definitely in their interest.

So far, there are only a few examples of TSO involvement in projects regarding use of demand side regulation objects as reserves options. However, in the long run investments in large scale in AMR-schemes and quality improvements of the metering values should be in their interest.

3.2.3 Network Owner

Requirements from the authorities e.g. regarding hourly metering for larger customers, rationalised management of meter information, reduced need for strengthening or expansion in congested parts of the distribution network and the possibility to introduce new functions and services are the main motivations for investments in technology for AMR.

Remote load control and the possibility to close down or open installations remotely are additional options if the specific AMR-technology used involves Direct Communication with potential of transmission of control signals.

In countries where the Network owner is responsible for collection of the metered data that are used for market settlement, it is also necessary to invest in software and computer systems that secure the whole meter value chain (CIS /MVDB).

Web based customer information and interactive load control via the Internet is already an option and fast development of these kinds of services is expected.

3.2.4 Supplier

The main interest of the supplier is to receive accurate meter values in time for the settlement procedures, and to develop new products with the potential of increased profit and reduced risk.

Hourly, or more frequent metering, and thereby increased knowledge of the load curve of different customers, could be utilized to improve the accuracy of the bids offered in the spot market. This could reduce the potential extra costs due to unbalances. The word "could" is used because additional investments in data handling procedures will be needed. It is therefore questionable if the supplier will be interested in financing the AMR as such.

Remote control of reducible loads might be of special interest for the supplier. In the Norwegian pilot VI automatic load reductions in periods with high spot prices were offered in combination with a spot price product on an hourly basis. This example shows that the supplier might be willing to pay the Network Owner (or others) for load control services in order to improve his product spectre.

Another aspect regarding load control is the potential of reduced risk in case of high spot prices. This could be achieved via bilateral contract with consumers that will reduce their load in case of high spot prices. In this context both local and remote control would be options.

Web based services to customers is of growing interest and concepts where customers are offered the possibility to follow their own consumption will probably be more focused in context with extended AMR.

3.2.5 Customer

Lower electricity bills and/or other potential economic benefits are assumed to be the main drivers for the customer. More frequent and more accurate meter reading makes it possible to be credited load reductions in high price periods and is of this reason in the customers interest. That does not necessarily mean that the customer is willing to pay the cost for new meters and AMR. One could guess that most customers would leave that to the network company that to some extent can cover these costs via the network tariff.

The potential of cost reduction and profit for customer are highly dependent on the network tariffs and product from the supplier. There are several examples of investments in local load control systems that are related to the e.g. ToU tariffs or even standard power tariffs where the price difference between high and low price periods is significant.

Larger customers with the possibility for selling back power in peak load situation (Demand Side Bidding) might be interested in contributing to investments in needed improvements in meters and load control schemes.

Some customers might be willing to pay for web-based services that could provide detailed information about own energy consumption.

3.2.6 Others

New "agents" who are involved in demand response market options, are other actors that will be interested in investments in new technology for AMR and load control. Aggregation of loads for Demand Side Bidding and metering/ settlement on behalf of the Network Owner and/or the Supplier could be opportunities for these agents. Payment for metering and load control services and in some cases investments in separate systems for AMR and/or load control could be options for these agents.

The summary of the different actors' interest in investments in the technology in question is indicated in table 3.1.

Table 3.1 Different actors' interest.

Technology		Customer	Network Owner	Supplier	Other service providers
AMR		More accurate metering	Obligation in some countries More efficient meter value processing	More accurate metering (Willing to pay for service, but not for investments?)	(Willing to pay for service?)
Load Control	Remote	Reduced bills if load is reduced in peak price periods	Peak load reduction to avoid grid investments	Peak load reduction as a part of energy contract offered to customers (Willing to pay for service?)	(Willing to pay for service?)
	Local	General energy saving and peak load reduction			
MVDB / CIS			Important part of the "meter value chain" e.g. for quality assurance	(Willing to pay for service?)	(Willing to pay for service?)
Web support		Load curve and price profiles Information of and response to products offered	Customer information Web based load management	Customer information Market place	Customer information Market place

4 Cost/benefit analyses

One important aspect when considering introducing some kind of varying electricity prices is the outcome of the cost-benefit analysis of the experiment.

The analyses of the experiments have usually showed a lack of welfare justification because the costs of the equipment needed for hourly metering of the energy consumption exceeds the benefits. However, with new technology, the costs might become lower than the benefits. Regulations and/or dedicated subsidies from the authorities might be needed if the net corporate benefit remains negative, provided a positive socio-economic outcome of the investment.

We are looking at the cost/benefit for investments in technology for Automated Meter Reading and Load Control separately; even if these aspects are closely related since the same communication infrastructure can be used.

This discussion of the cost/benefit analyses is based on the methodology described in the "Guidebook for B/C Evaluation Of DSM and Energy Efficiency Service Programs" prepared for the European Commission in 1996 [4], and on the description of the different actors interest for investments given in the previous chapter.

4.1 Description of methodology

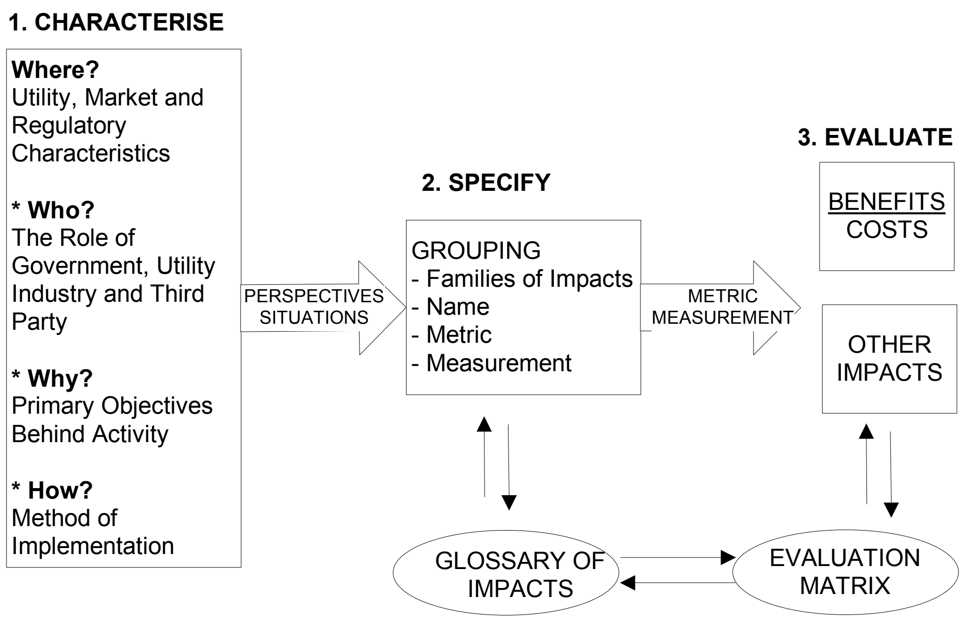


Figure 4.1 EUBC methodology.

Figure 4.1 provides and overview the EUBC methodology, which is divided into 3 main steps with the following descriptions.

4.1.1 Characterisation

The main outcome of the characterisation process is an improved understanding of the situation at hand and the perspectives to be included into the analyses. Four issues have to be addressed:

- *Where* – Characterisation of the environment in which the program is being implemented, included market description, industry structure and type of regulation.
- *Who* – The role of the actors involved
- *Why* – For what reason is the program being preformed? For example, are the programs being a part of a public policy or a part of a business strategy.
- *How* – What are the method of implementation. Investments needed, new tariffs, contracts, information and other specific efforts.

In the EFFLOCOM project the answer to these vital questions might differ slightly from pilot to pilot. The following table gives an indication of the main aspects involved:

Table 4.1 Characterisation.

Question	EFFLOCOM Characterisation
Where	The Danish, Finnish and Norwegian pilots (pilot I, II, IV, V, VI) are carried out in a deregulated market regime with focus on smaller customer and remote control of large and/or aggregated loads. The French pilot (pilot III) is peak load control scheme for medium sized customers, implemented before deregulation.
Who	Investments are done by the Transmission System Operator (pilot I, III), network owner (pilot IV-VI) and estate owner (pilot II)
Why	Public policy (pilot IV-VI) Business strategy (pilot I, II, III)
How	AMR and load control via direct communication (pilot I, VI) Remote load control (pilot IV and V) Local control initiated by the System Operator (pilot II) Direct communication and local control (pilot III)

4.1.2 Specification

The main outcome of this process is an improved understanding of which impacts to include in the evaluation. The following aspects are relevant for the EFFLOCOM project:

- Infrastructure capital investments
- Operational costs
- Rationalization of services
- Load reduction
- Alternative Generation capacity costs
- Energy taxes

4.1.3 Evaluation

This step compiles the impacts in a manner that allows a consistent comparison of alternatives. Experience in performing these evaluations has shown that both qualitative and quantitative impacts should be used in the evaluation.

One important aspect of this method is the specification of the boundaries, such as whether or not to include government costs and benefits related to taxes etc.

Quantitative methods
Quantitative analyses are most often used in cost/benefit analyses. Quantitative methods seek to measure all benefits and costs into monetary units, which is the dominant and to some extent the most difficult task. Cost effective outcomes may be expressed either as having a positive net present value (NPV) or having a benefit (B)/cost (C) ratio (BCR) in excess of one. In both cases the basic idea is simple: a program is cost effective if and only if benefits outweigh costs. Formally, the equivalence between NPV and BCR can be expressed as:

$NPV = B - C$ or $BCR = B/C$

To organize the analyses an evaluation matrix has been developed as shown in Table 4.1. The matrix is adapted to the actors in question in the EFFLOCOM project.

Table 4.2 Principle cost/benefit sheet.

Perspective	Costs	Benefits	B/C or NPV*	Other impacts
Customer				
Network Owner				
Supplier				
System Operator				
"Others"				
Society				

*) B/C: Benefit /cost ratio, NPV= B-C : Net Present Value

Qualitative methods
The principal motivation for using a qualitative approach relates to the problem of monetizing relevant attributes. In this alternative approach all relevant benefits and costs keep their original units, and the evaluation becomes a qualitative task of trading off benefits and costs to find the best solutions.

4.2 Cost and benefit for involved actors

The following presentation gives a qualitative view of the benefits and cost referred to the different technologies in question. The discussion is based on the description of the interest from the different parties described in the previous chapter.

4.2.1 AMR

Stakeholder: Network Owner, Supplier
Benefits:
- Reduced costs due to improved metering quality and rationalization (Network Owner)
- Improved metering quality and new market options (Supplier)

Costs:
- Investment and operational costs for new meters and communication

4.2.2 Remote Load Control

Stakeholders: Network Owner, Supplier, Customer

Benefits

- Reduced need for investments in the network (Network Owner)
- Potential profit from sales of load control services to Supplier and Customer (Network Owner)
- Potential profit of new products involving load control (Supplier)
- Potential of reduced electricity costs (Customer)
- Potential of demand side bidding (Customer)

Costs

- Investment and operational cost (Network Owner)

4.2.3 CIS and MVDB

Stakeholders: Network Owner, Supplier

Benefits

- Improved quality of metered data (Network Owner + Supplier)
- Potential of sale of meter values (Network Owner)

Costs

- Investment and operational cost (Network Owner)

4.2.4 Web based services

Stakeholders: All

Benefits

- Improved service level (All)

Costs

- Investments and operational costs (Network Owner, Supplier, Agent (probably different systems linked together?))

4.2.5 Example Cost/Benefit pilot VI

Several actors may benefit from establishment of AMR and RLC as described above. However, none of the actors have economic incentives to establish the technology alone. So far there are no arrangements for cooperation between the different actors. In Norway, the network owner is the natural actor for the technology investments. As expected, the cost/benefit analysis performed in the Norwegian pilot "Consumer flexibility by efficient use of ICT" gives negative corporate profitability. The costs (C) includes both investment and operational costs and the benefits (B) are related to more efficient meter handling, postponed network investments and more accurate accounting.

The average figures were:
C= ~94 € / point / year
B= ~24 € / point / year
NPV = B – C = ~-70 € / point / year

It is important to note that these figures also include extra ordinary costs due to problems with technology. These costs will probably be reduced when the technology is better tested. Research and develop can also contribute to more well-working technology, i.e. standardization of interfaces between AMR systems and other IT-systems like CIS and MVDB. Also the operational costs will be reduced with more well-working technology. Additionally, improved utilisation of the technology will make it possible for the network owner to raise the benefit figures.

Consequently, the potential of improvement of the network owner cost/benefit is significant. However, financial contribution from the authorities and/or other stakeholders (suppliers, customers) seems to be needed to secure the project economy.

4.2.6 Example Cost/Benefit pilot I

The Danish pilot doesn't include a full cost/benefit analysis including costs and benefits for Customer, network owner, supplier, system operator and society.

The pilot includes a comparison of the flexible load to investment in further production to be used in the few hours where it is difficult to meet the demand.

Based on actual costs in the pilot and evaluation with the manufactures of hardware and software as well the installers, the cost of equipment, software and installation is evaluated to be 800 Euro per house in case the installation includes 1000 houses. The pilot shows that 5 kW/house can be interrupted at cold days. Assuming that the 5 kW/house also counts for the 1000 houses, the investment is equal to 160 Euro/kW or 31 Euro/kW per year (10 years, 7%).

As a comparison, the investment for gas turbines is around 80 Euro/kW per year (10 years, 7%). This analysis thus indicates that investment in flexible load is a good investment.

The customers in the pilot have during the winter 2003/2004 in average saved 80 Euro by offering flexible loads for electric heating and on top of this they have in average obtained 40 Euro in energy savings. In case the control system also comes to include customer facilities for lowering (interrupting) the heating in periods during the day and/or night, the benefits for the customer are estimated to be much higher. The customer may thus be willing to pay a part of the investment in equipment, software and installation.

5 *Conclusion*

The main customer incentives for load reduction are related to the price signals given by the network tariff and the energy price. Experiences from the EFFLOCOM project and previous studies indicates that the following tariffs and energy products gives the best motivation for load reduction:
Network tariffs:

- ToU-tariffs with inter day variations in price
- Dynamic tariffs that are amplified in periods with shortage

Energy Price:
- Hourly spot price
- Hourly spot price combined with automatic load reduction when spot is high
- ToU-price e.g. with day /night variation

Bilateral contract for load reduction is an alternative to price elasticity efforts. Most of the schemes implemented relates to system operator products for reserves and reliability purposes. The Nordic TSOs have all utilized interruptible or reducible loads as capacity reserves. Mainly larger industrial loads are used, but aggregated minor loads are also an option.

The need for reliable documentation and controllability of some of the loads lead to the conclusion that investments in technology are necessary. The most interesting investments are related to automated meter reading, load control and web based support. But supplementary investments in the backup systems in the meter value chain might be needed to secure the quality of the metered data.

So far investments in technology have been limited of economical reasons, because the different actors do not find profitability alone. More cooperation between the stakeholders and regulatory arrangement are needed to secure that projects that are proven socio-economic beneficial will be accomplished.

In general stable regulations and tax policies from the authorities are needed to reduce the regulatory risk of investments.

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