Smart metering

Subtask 5, Report n:o 5

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in co-operation with the country experts

International Energy Agency Demand-Side Management Programme

Task XVII: Integration of Demand Side Management, Distributed Generation, Renewable Energy Sources and Energy Storages

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EXECUTIVE SUMMARY - Smart metering

TASK XVII: INTEGRATION OF DEMAND SIDE MANAGEMENT, DISTRIBUTED GENERATION, RENEWABLE ENERGY SOURCES AND ENERGY STORAGES

Task extension: The effects of the penetration of emerging DER technologies to different stakeholders and to the whole electricity system

Background

Energy policies are promoting distributed energy resources such as energy efficiency, distributed generation (DG), energy storage devices, and renewable energy resources (RES), increasing the number of DG installations and especially variable output (only partly controllable) sources like wind power, solar, small hydro and combined heat and power.

Intermittent generation like wind can cause problems in grids, in physical balances and in adequacy of power.

Thus, there are two goals for integrating distributed energy resources locally and globally: network management point of view and energy market objectives.

Solutions to decrease the problems caused by the variable output of intermittent resources are to add energy storages into the system, create more flexibility on the supply side to mitigate supply intermittency and load variation, and to increase flexibility in electricity consumption. Combining the different characteristics of these resources is essential in increasing the value of distributed energy resources in the bulk power system and in the energy market.

This Task is focusing on the aspects of this integration.

Objectives

The main objective of this Task is to study how to achieve a better integration of flexible demand (Demand Response, Demand Side Management) with Distributed Generation, energy storages and Smart Grids. This would lead to an increase of the value of Demand Response, Demand Side Management and Distributed Generation and a decrease of problems caused by intermittent distributed generation (mainly based on renewable energy sources) in the physical electricity systems and at the electricity market.

Approach

The first phase in the Task was to carry out a scope study collecting information from the existing IEA Agreements, participating countries with the help of country experts and from organized workshops and other sources (research programs, field experience etc), analyzing the information on the basis of the above mentioned objectives and synthesizing the information to define the more detailed needs for the further work. The main output of the first step was a state-of-the art report.

The second phase (Task extension) is dealing with the effects of the penetration of emerging DER technologies to different stakeholders and to the whole electricity system.

The main subtasks of the second phase are (in addition to Subtasks 1 – 4 of the phase one):

Subtask 5: Assessment of technologies and their penetration in participating countries

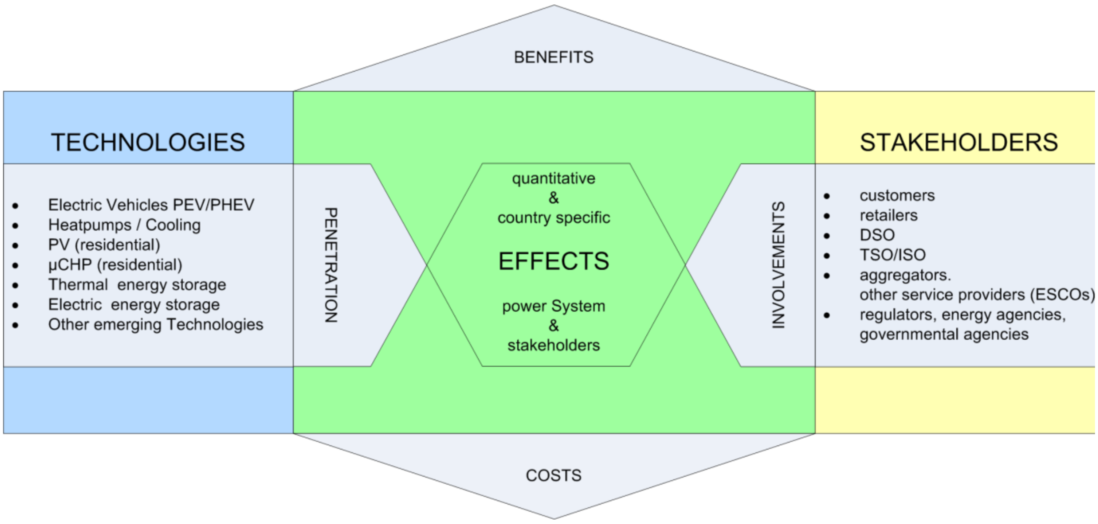
Subtask 6: Pilots and case studies

Subtask 7: Stakeholders involved in the penetration and effects on the stakeholders

Subtask 8: Assessment of the quantitative effects on the power systems and stakeholders

Subtask 9: Conclusions and recommendations

The figure below describes the concept of this extension.



Results

The report analyzes the technologies, regulation, costs and benefits as well as experiences of smart metering. It also describes the current situation of smart metering in the participating countries. Short summary of this is as follows.

Austria

According to the new Electricity Act (ElWOG 2010), the Minister of Economy may introduce smart metering per decree, following a cost-benefit-analysis. The regulator may define functionalities and data requirements of a smart metering system. Current situation in Austria is that approx. 40.000 smart meters are installed, and it is planned that 80% of the customers will be equipped in 2020 according to the EU rules..

Finland

Currently, the number of the AMR meters is increasing rapidly in Finland, because almost all DSOs have AMR meter installation work ongoing. This is mostly due to the "Government Decree on settlement and measurement of electricity transactions (66/2009)". Based on the decree, at least 80 % of the customers have to be measured with AMR meters by 31st of December 2013. However, it is assumable that penetration will be almost 100 %, since most of the DSOs are installing AMR meters for all customers during their AMR installation programs. More than one million meters have been installed

France

ERDF was asked by the CRE (Energy Regulation Committee) to experiment an advanced smart meter counting system, based on recommendations made in the CRE's declaration of the 6th of June 2007. This LINKY pilot project consisted 300 000 meters and ended in March 2011. The CRE validated this experimentation. The deployment objective of smart meters is 35 million smart meters installed in 2020.

The results being positive, this project prefigures the national deployment of smart meter systems in France, though some points are still being discussed as, for instance, what kind of information and services suppliers should provide to their clients in order to help them reduce their consumption and at what price? By the end of 2011, there are still political discussions concerning who shall finance the system and who will own the meter (ERDF or local distribution managers).

The Netherlands

The Dutch Government plans to roll out smart meters following Electricity Directive 2006/32 EC. The bill concerning the rollout was adopted in February 2011 and was followed by an Order in Council ("Algemene Maatregel van Bestuur" or "AMvB") which came into effect on January 1st 2012. This Order determines the functions of the Smart Meter on which the final standard should be based. The Grid Operators (GO's) in the Netherlands are responsible for the roll-out of smart meters, for both gas and electricity

There are currently about 8 million electricity meters and 7.1 million gas meters in the Netherlands. In a period starting in 2012 up to 2020, 80 percent of these meters will be replaced by smart meters

From the first of January 2012 the GO's will start with the small-scale rollout. During a two year period the GO's will be placing smart meters:

- In new domestic houses
- As part of regular replacements of old meters
- In case a customer requests a smart meter.

The GO's plan to install smart meters at 450.000 households in these 2 years. As most Dutch households are dual fuel consumers, this amounts to almost double that number in terms of actual meters. The large scale rollout is planned to start on January 1st 2014.

Spain

In 2007, since the publication of the "*Reglamento Unificado de Puntos de Medida"* (RD 1110/2007) and of the "*Orden Ministerial por la que se regula el control metrológico del estado"* (ITC/3022/2007), the regulatory framework for smart meters in the residential sector establish new functionalities to be implemented in the meters.

At the end of 2007, Spain approved the National Plan for Meters Substitution which involved the obligation for distribution companies to change 26 millions of meters in the residential sector in Spain for 2018. In addition consumers will pay around 15 % more each month for the smart meter rent since the moment that they have a new meter.

However the delay in the implementation of this plan has motivated a revision of milestones in the Orden IET/290/2012 maintaining the target of 26 millions of meters for 2018 but rescheduling the milestones.

In Finland the minimum functional requirements for the smart meters are defined, in other countries they are still under discussion and the requirements seem to be varying depending on the local circumstances and market regulations.

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1. Basic concepts

There is no single definition of smart metering, however all smart-meter systems comprise an electronic box and a communications link. At its most basic, a smart meter measures electronically how much energy is used in a certain time-interval, and can communicate this information to the utility or other actor responsible for metering. This information can be shared with end-use devices to let the customer see how much energy they are using and how much it is costing them [1]. Definition in [2] is "Advanced metering is a metering system that records customer consumption [and possibly other parameters] hourly or more frequently and that provides for daily or more frequent transmittal of measurements over a communication network to a central collection point".

The key distinction between smart-meter types is determined by their communication i.e. whether there is any with the energy supplier, whether this is one-way or two-way and the data-storage capability of the meter. The combination of these features determines the extent to which the metering system can help customers reduce their energy usage and minimise carbon emissions.

In most countries there are no adequate requirements for functionality of smart meters. The lack of common requirements increases costs of smart metering systems and makes it expensive to develop, maintain and implement market applications and services that are based on smart meter data. Some examples of common minimum requirements for smart meter functionality can be found ([4], [5]).

The frequency or duration of meter intervals depends upon the electricity provider's tariff and rate designs. The requirements for billing metering stem from the tariffs applied. In principle, it is not necessary for the metering system to know the tariff applied. It is enough that the meter meters both the consumption and production of active and possibly reactive power separately (so called four quadrant metering) with the time resolution required for the tariff. In the Nordic countries this time resolution is 1 hour, in some other countries it is 15 or 30 minutes. Consumption and customer-initiated generation usually have different tariffs. Meter data can be stored in the meter for days or weeks before it is transferred to the utility's meter data management system. The data must be reliable and accurate. Lost or erroneous data may cause significant costs, but transactional communication mechanism can avoid this.

Apart from solid 'back-office' applications receiving the metering data, detection of meter faults, erroneous installation and tampering is useful. Compensations for long voltage interruptions are also quite often included in the billing. Compensations for some power quality defects are also tentatively considered. Thus registering of voltage interruptions and perhaps even some basic power quality characteristics may be required for the billing meters of the future.

Data communication with the meter shall be such that the accuracy of the measurement data produced by the meter is not reduced due to data communication. The accuracy requirements of static billing meters are defined in IEC 61036 standards. It is reasonable to require that the hourly or 15 minute values required by the tariff maintain the original accuracy. In other words the data communication may not be the biggest source of measurement error. Typical source of such unacceptable inaccuracy is too large pulse size of pulse metering.

Cyber security of smart metering and privacy of customers and electricity market data are not discussed here in details although cyber security is considered in many countries to be a critical issue. Privacy questions and data availability should be defined in legislation.

2. Functionalities of smart meters

As mentioned above, there are no common requirements for the functionality of smart meters. In many countries there are not adequate requirements for functionality. In principle, the functions of a smart meter include some or all of the following:

- consumption measurement and recording with the time resolution applied in the electricity market (15 minutes, 30 minutes or 1 hour depending on the market) and storing such measurement data at the meter a specified minimum time such as 60 days.
- remote reading
- daily remote reading
- visual display on meter
- communication with data security
- tamper detection and detection of installation errors
- remote time clock synchronisation
- load management via the meter with a dedicated controlled circuit
- power factor measurement
- import and export metering of energy
- remote connect and disconnect of power
- control of supply capacity limit and/or measurement of peak power
- interface with local automation network or home automation network (eg. ZigBee, Ethernet, etc.)
- monitoring interruptions, quality of voltage and events
- meter loss of supply detection
- remote configuration and software upgrades
- plug and play device commissioning

This list is mainly based on [4].

The additional cost for additional functionalities is low in large scale applications. Often too much emphasis has been but on not having any unnecessary functionality in the meters. This often leads to higher costs than having one common requirement that covers all common needs. This is also problematic for many applications that need metered data or transfer of simple control signals.

3. The role of smart meters [19]

Since 1 July 2007, all European citizens can freely choose their electricity and gas supplier. Same applies also to some other markets around the world. However, market opening as such cannot guarantee a sufficient degree of supplier choice and competition. Smart meters may facilitate better services for customers in various ways. More accurate metering and billing is an obvious advantage.

Today, customers with floating prices do not get an accurate bill as in most countries where price based varying tariffs are offered to household customers, consumption is distributed according to one or more standardised profiles. Consumers with a consumption pattern that differs from these standard profiles will get an inaccurate bill, especially if prices fluctuate a lot. In countries where self-reading is practiced, smart meters will make those manual readings obsolete. Smart meters will also facilitate supplier switching. With smart meters, a customer can make a switch any day of the week, and meter reading can be done automatically without involving the customer. Both for the customers themselves and for the power system as such, it is important that the price signals from the wholesale market get through to the retail market.

With Automated Metering Infrastructure (AMI) technology and a display showing both consumption and price, the customer can reduce consumption when prices are high and get full benefits from it with accurate metering and billing based on the actual consumption. In this way, customers can save on their electricity bills. Retailers can compete by offering customers different electricity prices which apply at different times of the day. Similarly, retailers can target certain groups of customers with particular tariffs that would be most economical for their consumption patterns. Such pricing innovation and variety in smart meters will promote retail competition to the benefit of customers. Especially for households with relatively high electricity consumption, house and building automation can lead to additional savings and increased comfort: optimisation of heating and lighting of the household and small business.

For customers that are fuel-poor or want to be more in control of their spending on electricity, prepayment meters are an option. With such meters, the customer can pay in advance and get a message when it is time for an additional payment. Even for that purpose smart metering can be more cost-efficient than prepayment meters, depending on the local conditions.

Looking at the broader picture, reducing greenhouse gases emissions and global warming will be of benefit to everyone, including consumers. Smart metering can lead to a reduction in peak load demand and also electricity consumption in general. This will possibly result in reduced CO_2-emissions from generation based on fossil fuel.

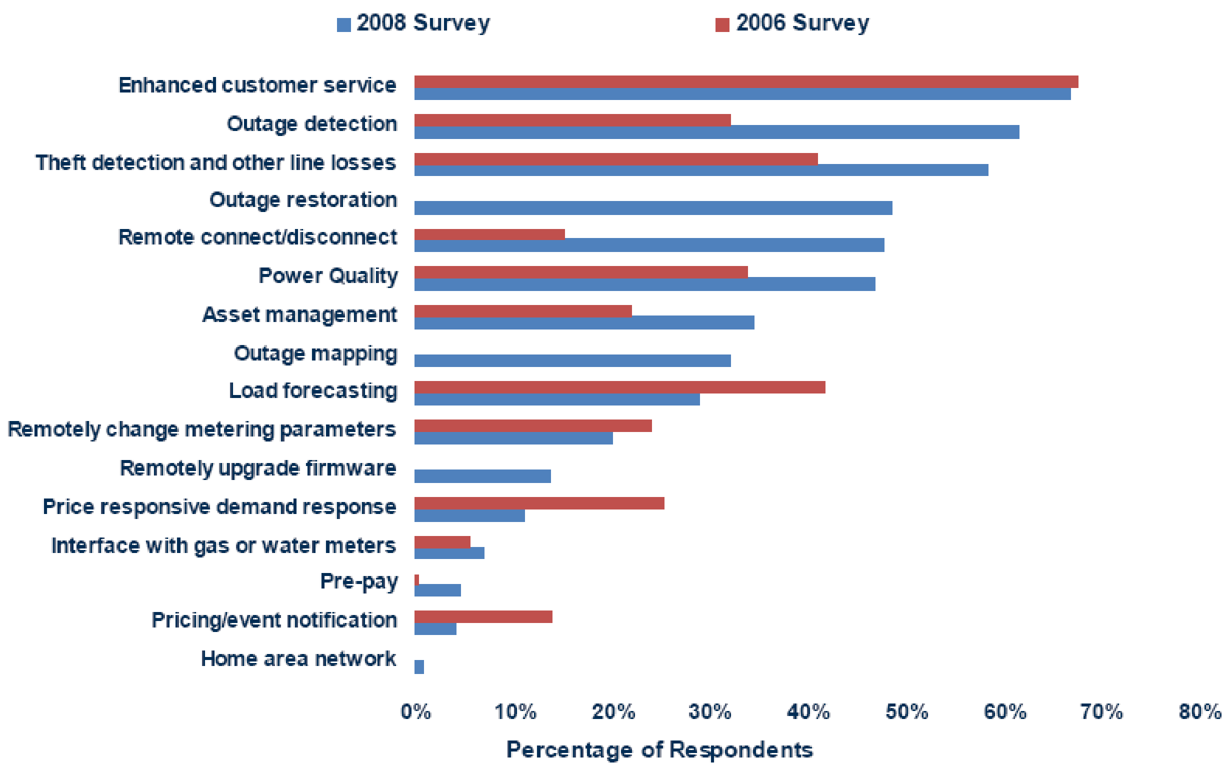
Smart metering infrastructure for small-scale consumers is not an objective in itself. International experience indicates that the reasons for metering innovation vary among countries. The main driver in several countries is the hope that exposing consumers to a time varying cost of electricity will lead to a reduction in consumption and to a reduction of peak demand, reducing the need for additional investments in networks and generation. In turn, increased energy efficiency will translate into savings for consumers and the system as a whole. In particular, policies adopted in the States of Victoria (Australia), California (USA), and the province of Ontario (Canada) were clearly motivated by a need to manage high and increasing summer peak demand driven by increased air-conditioning use.

A need for improved billing accuracy was the main driver to introduce smart meters, for example in Sweden. Shortly after deregulation of the electricity market, energy prices soared while consumer groups heavily criticised electricity bills for being both unclear and inaccurate. Sweden has introduced, from July 2009, a legal requirement for all electricity meters to be read monthly. The most cost effective way distribution companies could meet this requirement is to invest in remote meter reading technology. In addition, environmental concerns are a strong driver for power conservation in Sweden.

Italy indicated the billing accuracy as one of the main objectives to be pursued as well. The requirement to reduce losses due to fraud is of prime importance in both Italy and Northern Ireland where the scale of the losses, and costs associated with their detection, were significant. In particular, Enel, the dominant distribution (and retail) company in the domestic sector in Italy has invested in smart metering for a number of business driven reasons:

- Limiting the large number of visits per year.
- Reducing bad debts.
- Getting into a good position before market opening in July 2007.

In the USA similar to the 2006 FERC Survey [2], the 2008 FERC Survey [6] asked respondents how their entities use advanced metering, beyond interval meter reading collection. Figure 1 shows the results for 2006 and 2008. Respondents identify increased use of newer types of advanced metering functionality, especially the use of advanced metering to perform remote outage management and to remotely upgrade firmware on the advanced meters. Enhanced customer service is the most often cited use of advanced metering by respondents, as it was in 2006.



Source: 2006 FERC Survey and 2008 FERC Survey

Figure 1. Reported uses of advanced metering in 2006 and 2008

4. Cost-benefit analysis of Smart Metering

The range of potential benefits from smart metering can be rather extensive. For instance, if peak shaving is the main driver for smart meter deployment, the expected cost savings derived from generation and network investments deferral should be quantified first. Then there are additional benefits like enhanced system security, or cost savings in meter reading. It is important to remember that not all benefits can be quantified (or quantified with a given accuracy).

Estimation of the costs of smart metering is more straightforward although the costs are highly dependent on the local circumstances, on the functional requirements and on the selected technologies.

The cost-benefit analysis of smart metering is a complicated process and depends on many factors; especially it is important to define the scope of the analysis: is that the investor point of view, network operator point of view, are all stakeholders included, are societal aspects taken into account etc. No simple guidelines can be given. In the following mainly cost and benefit components are discussed, but no detailed proposal how to do it is not tried to give.

4.1. Analysis of costs on the basis of experiences

4.1.1. Cost components [19]

In assessing the costs of smart meter deployment, two main cost categories are identified:

- New costs: new capital and operation and management (O&M) costs attributable to smart meters;
- Stranded costs: equipment and systems that may be displaced by smart metering;

New costs

Smart Metering cost-benefit analyses include capital costs for meters, communication, associated systems for data handling and installation; operating and management costs for reading, service, and re-verification. Note that costs vary significantly with the type of meter and with the communication infrastructure (PLC, GSM/GPRS, ADSL or cable). A higher frequency of billing and installation of displays at customer site (where consumer have always direct information about their consumption and its associated costs) could increase costs.

- **Capital costs:** Capital costs of smart meters are the fundamental cost category in the analysis. Assumptions regarding the technology, the depreciation rate, the timing and scale of the roll-out programme and the lifetime of the metering assets are crucial for the results. Moreover, installation costs differ across countries because of differences in labour costs.

  A cost analysis can estimate an average figure, but the cost per meter will vary among utilities because of geography, customer density and customer type.

- **Operation and management (O&M) costs:** Operation and management (O&M) costs of smart meters are an important cost category. Quantifying O&M costs for a new technology is complicated by extremely limited operating experiences. Estimates tend to fall within wide ranges and can vary significantly depending on which technology is adopted and what economies of scale are assumed. As a general average, the Ontario Energy Board (2004) estimates communication maintenance is about 1% of the installed capital cost of the system. Data storage and management are thought to become a much larger task for distributors/metering companies than presently and the costs may be significant. Presenting smart metering data to the customer is another new cost that might potentially be large, depending on the frequency of updating information and the quality of the presentation. Estimates can include or exclude new operating costs that are not now being incurred. An example of this is meter re-verification costs. Electronic meters have to be tested more often than electromechanical meters, so the cost of ensuring accuracy will increase with smart metering.

Stranded costs

It is important to note that most residential and small commercial customers have electromechanical meters that record cumulative energy consumption only. All electromechanical meters will be rendered obsolete by smart meters and there is limited potential to reuse this hardware. Some electronic meters might be adaptable to smart metering systems. However, in general, stranded costs, also excluding the cost of removing and handling the old meters, are expected to be of minor importance.

4.1.2. Experiences

Figure 2 shows the cost benchmarking of several projects presented in 2006 report [2] and Figure 3 shows the breakdown of costs. Detailed estimates on how the total costs are constituted from individual cost items can also be found in the detail reports of the cost benefit analysis of NERA [4].

It has to be noted that the costs of the actual meter hardware are usually less than 50 % of the total costs per meter. Installation costs depend highly on the existing metering infrastructure and can in some cases be about the same magnitude as the actual meter hardware.

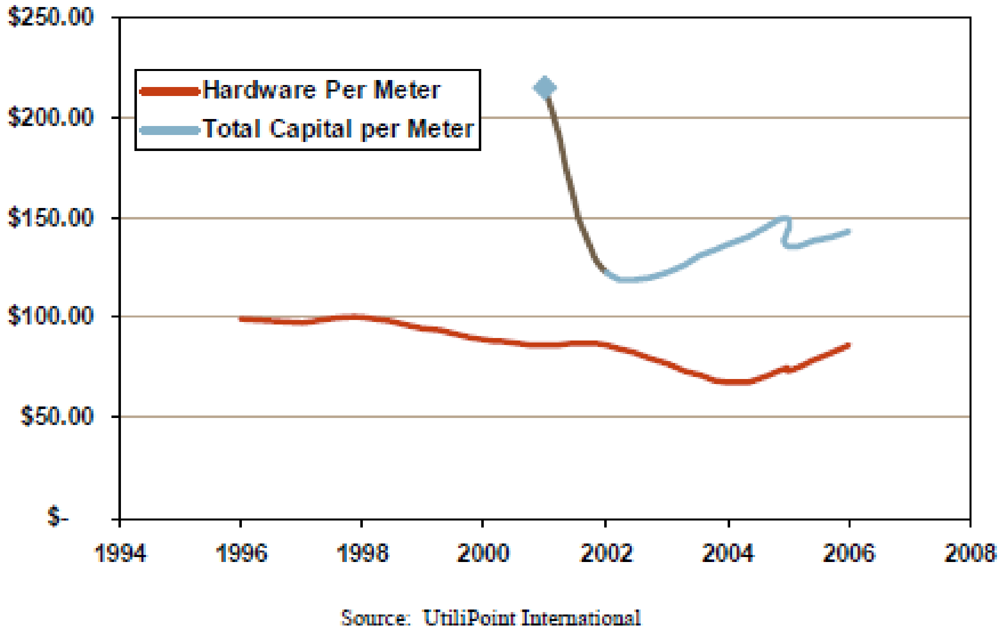


Figure 2. **Total AMI capital and hardware costs per meter [2]**

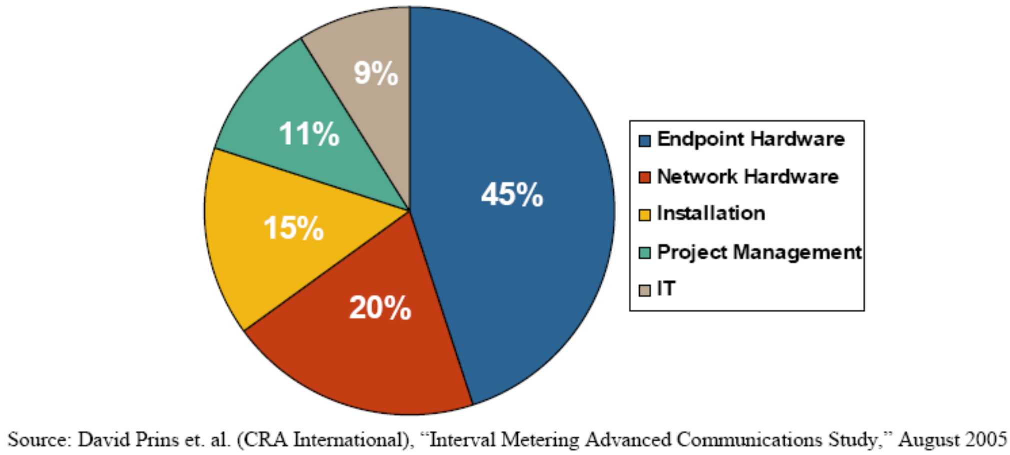


Figure 3. **AMI System Cost Breakdown**

The reported costs per meter of different planned or implemented projects vary in large scale between 70 – 450 €/meter (for ex. [2], [7], [8]). They depend for ex. from the cost categories included, size and timing of the projects, geographical conditions etc. and are not directly comparable.

After checking source, some corrections were made and further analyses of the selected cases were carried out. Also some more cases reported in other sources were added and all together 24 cases were analysed. These include 6 cost analyses, 5 completed projects, 5 projects that started before 2008 and 7 projects starting 2008 and 1 starting 2009. The Figure 4 is plotted from data of these 24 cases.

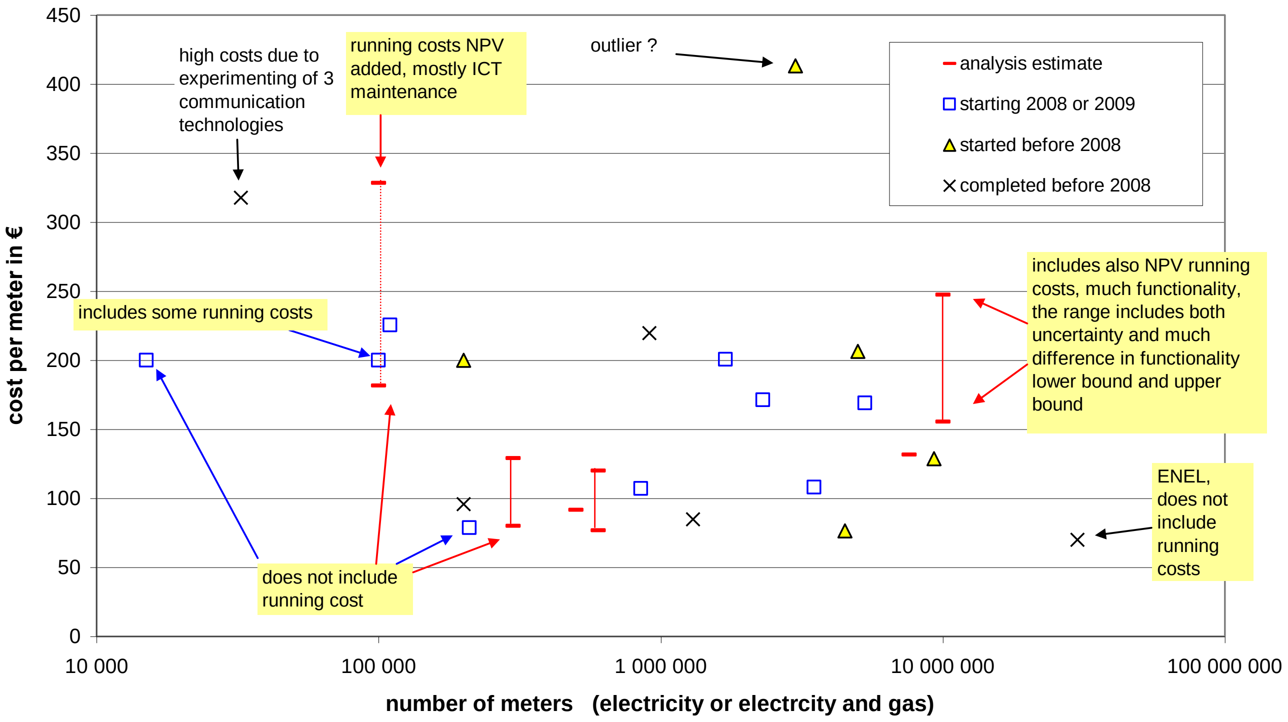


Figure 4. Cost per smart meter vs. implementation scale in 24 reported cases (source: Pekka Koponen, VTT)

The costs shown in the Figure 4 are still not directly comparable. In most of these cases it has not been reported what costs are included. In many cases it is either known or likely that the estimated running costs of communication, operation and maintenance are not included. Depending on the system and its use these can be estimated to be from 25% to over 50 % of the costs. In reality, the running costs easily exceed the estimated costs, because of unexpectedly high number of site visits due to design errors or poor reliability. In some cases the investment in IT systems is not included and it may be around 20 % of the costs. The value and expected lifetime of the replaced meters can vary much and the stranded costs can be taken into account very differently. The assumed rates of interest can be different. The cases come from Europe, UK, Australia, USA and Canada and the results depend on the variations of the exchange rates of the currencies.

Reporting of running costs is not comparable either. In some cases only costs of data communication and meter maintenance have been reported. Maintenance of information systems can be omitted or included. Especially for smaller systems (some 100 000 or less meters) the maintenance of information systems can form most of the running costs.

In Canada and in the Nordic countries the installation costs are high. It is also well known that the installation costs are very sensitive to the installation schedule, good planning of the installation, number of exceptions that need to be handled individually and availability of service companies that could do most of the installation as their low priority background work.

The Figure 4 shows that the scale of the project clearly has a significant impact on the costs per meter, but there are many other things that affect the price, too. For example, the circumstances in

Italy, and the timing of the project were so favourable in the Enel project in Italy that it does not seem likely to achieve equally low costs in the other countries. The Italy case also gives support the finding of some cost benefit analyses that much functionality can be included in the meter without significantly adding to the costs, when very large numbers of similar meters can be produced.

The Figure 4 does not give support to the assumption that the metering system costs are now going down. Earlier the costs of remotely readable meters have dropped, but now functionality and performance of smart meters and related ICT are improving instead. This development is reasonable as there is more potential to increase benefits than reduce costs. Also increasing demand of smart metering systems may affect the prices of smart metering systems.

4.2. Benefits

The main problem in the assessment of the potential benefits attributed to smart metering systems is that the benefits are divided between different stakeholders which often means that the cost-benefit analysis is not always feasible if only one stakeholder (like DSO) is considered. In general the benefits can be classified for ex.

- For final customers to increase energy awareness and decrease energy use and energy cost.
- For metering companies or DSOs to decrease meter operation costs.
- For grid operators who want to prepare their grid for the future.
- For energy suppliers/retailers who want to introduce new, customer made services and reduce call center cost.
- For TSO in decreasing system peaks and introducing demand response programs
- For governments to reach energy saving and environmental targets and to improve free market

Benefits can be described also as operational and societal savings where

- **Operational savings** are discernible and measurable reductions in the utility's or metering service company's overall cost of meeting its service obligations that serve to offset some or all of the Smart Metering investment costs.
- **Societal benefits** accrue to consumers in the form of lower bills, and enhanced electric services, and sector adjustments that accrue directly to some consumers and indirectly to others processes.

Operational savings are easier to estimate and they are direct benefits to the investor of the smart metering systems. These savings can include for ex.

- savings in meter reading (regular and instantaneous)
- savings in metering data handling and transfer
- savings in network operation and investments
- income from services to other stakeholders
- etc.

When considering cost-benefit analyses from the point of view of the investor, these savings are usually considered.

In the report [9] these societal benefits are analyzed in more details. Figure 5 provides a summary of the processes by which these benefits are generated and to who they accrue. Because the primary benefits in some cases are measured in different ways, methods and protocols are needed to transform the physical manifestation into monetary terms. As the figure illustrates, there are four sources of directly attributable benefits and two forms of spillover benefits.

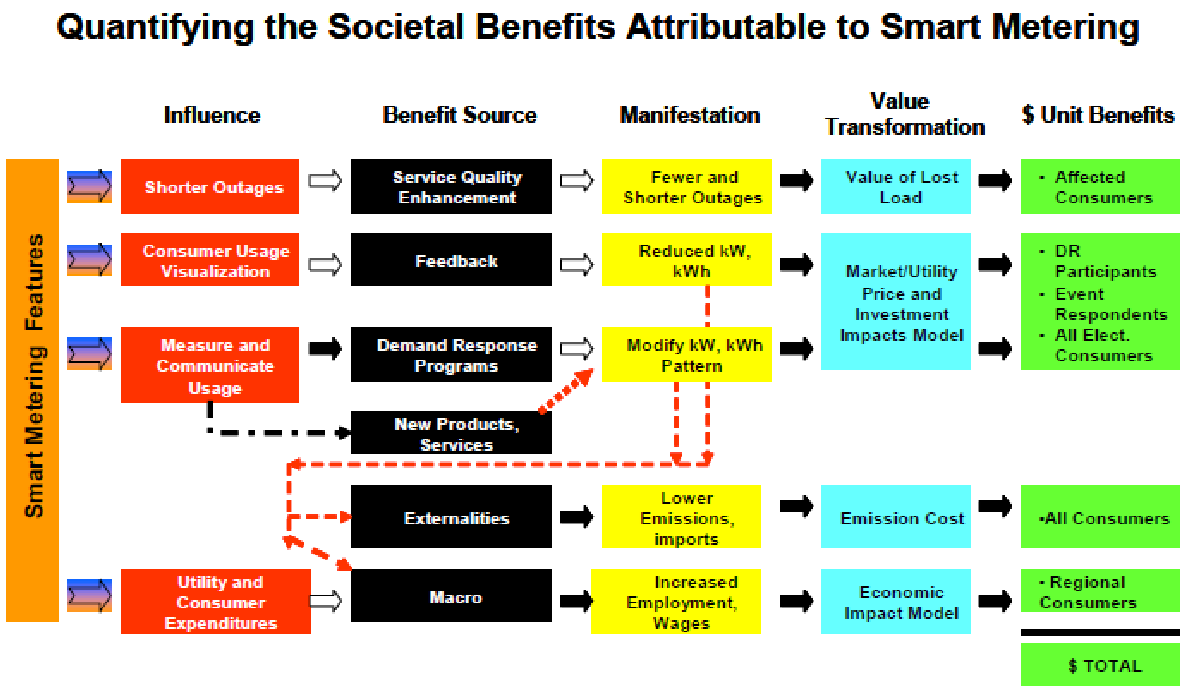


Figure 5. Source and Measurement of Societal Benefits [9]

The direct societal benefits are as follows:

- **Service Enhancement**. Smart Metering includes features that are the enabling factors, labeled as influences in the figure. By providing the utility with better information about the nature and extent of outages, Smart Metering influences the duration of outages. This benefit is manifested as improved service quality, i.e., shorter outages. One way to monetize these benefits is to use the value of lost load (VOLL) which equals the benefits (measured as kWhs of restored energy) times a measure of the value ($/kWh) consumer realize. Those affected by an outage are the direct beneficiaries. However, since every consumer is potentially exposed to an outage, these benefits may be treated as accruing to all electricity consumers since they all are presumably exposed to outages and the associated undesirable consequences.
- **Feedback**. Metering load at a very fine level of granularity (over hourly or shorter intervals) and making those readings available quickly and conveniently to consumers (direct feedback), may cause some of them to reevaluate how they use electricity and result in lower electricity usage. The benefits of this outcome accrue to those participants that reduce usage, but the benefits may also inure to all other electricity consumers.
- **Demand Response**. More precise metering and meter reading enables an increased scope and scale for demand response programs, which is manifested as load profile modifications measured as energy and demand changes. Like feedback, these modifications can trigger market adjustments that end up benefiting demand response participants and consumers in general.

- **New Products and Services**. Smart Metering can expand the scale and scope of the series that are provided by an electric utility creating, thus enhancing customer service and satisfaction and possibly resulting in additional revenues.

Other benefits are not realized directly, but are spillovers benefits, as indicated by the dashed lines in the figure. In those cases where energy and demand usage is modified, there are two additional potential streams of benefits:

- **Externalities.** Changes in energy and demand attributable to feedback and demand response, themselves enabled by Smart Metering, affect the sources of generation used to serve electricity demand and, to the extent that emissions are lowered or oil imports are reduced, possibly resulting in societal gains that all consumer enjoy, again demonstrating a collateral impact that affects sectors other than electricity.
- **Macroeconomic Impacts**. Behavioral changes enabled by Smart Metering can lead to macroeconomic impacts, including local economic activity such as changes in employment and wages that can potentially benefit all regional consumers.

5. Regulation and legislation

The **regulatory and commercial framework** is an equally important variable in the decision. Innovative metering has generally been introduced in an environment where metering activities have been the exclusive responsibility of the network operators. Network operators are often the retailer to the final customer and may well have energy generation interests. In many countries, metering is treated as part of the overall network business and is remunerated as part of the network price control. In this environment, the increased costs of the metering assets have generally been included in the network operators' regulatory asset base.

Where competition has been introduced in metering services (for instance in Great Britain), retailers, and not network operators, are primarily responsible for purchasing metering services: decisions about whether or not to invest in smarter meters for customers' homes are therefore commercial decisions for energy retailers. Regulatory interventions in these types of settings are more difficult to justify.

In the state of Victoria (Australia), where the industry is disaggregated, the regulator justified the need for intervention on the basis that benefits were spread across many different decision makers and that prohibitive information and transaction costs exist. The regulator argued that these factors would prevent the market from delivering smarter meters even if they would benefit customers and were cost-effective. In addition, DSI needs new concepts such as dynamic pricing, real-time pricing (not only smart metering).

Thus legislation and actions of regulatory authorities can have a big impact on how much smart metering is implemented and what functionalities and interfaces it includes. Regulation and legislation that affect metering can be related to:

- Unbundling due to the competitive electricity market.
- Metering responsibility
- Incentives to metering responsible actors

- Adequate functionality
- Adequate open interfaces and interoperability
- Availability and privacy of metered data
- Improving energy efficiency with the meters
- Rules that are difficult to meet without smart metering. These may be related to customer switching, meter reading frequencies, support for energy efficiency improvement, etc.
- Rules that require full scale AMR rollout within a specified time horizon.

It is important that regulation and legislation allow adequate time to update the metering systems. Too fast rollout increases costs and often makes it necessary to sacrifices critical requirements.

Table 1 gives the summary of the regulation in those European countries who are active in smart metering. It is based on [10] with updates from [1].

Table 1. Summary of smart metering related regulation in some European countries

Austria	According to the new Electricity Act (ElWOG 2010), the Minister of Economy may introduce smart metering per decree, following a cost-benefit-analysis. The regulator may define functionalities and data requirements of a smart metering system. A first draft of meter functionalities is available
Belgium	No legislation regarding the introduction of smart metering yet. However, smart metering is high on the agenda of all stakeholders
Denmark	Hourly metering (consumption > 200,000 kWh/year) was mandatory from January 2003. After January 2005 the limit changed to 100,000 kWh/year. There is no legal framework for the provision of smart meters for household customers. Mandatory metering of the electricity consumption of household customers has been suggested, but a cost-benefit-analysis led to a negative result. Minimum functional requirement for electronic electricity meters are available
Finland	From 1st of March 2009, government regulation requires that utilities install hourly meters for at least 80% of their customers by the end of 2013. Minimum functional requirements are also defined
France	Legislation is in preparation for a mandatory rollout. The goal is from January 2012 to only install electronic meters and have a 95% coverage by the end of 2016. This goal was enforced by a government decree in August 2010. The regulator defined some guidelines and minimum functional requirements for electricity meters. A cost-benefit-analysis with a positive result was presented in 2007.
Germany	A mandatory rollout is not planned. Germany follows a policy driven by customer demand. The metering service is liberalised. The national legislature (EnWG 2009) only demands to install smart meters in new buildings and buildings that are undergoing major refurbishing from the beginning of 2010. By 2011 electricity suppliers have to offer load-variable or time-of-use tariffs. Minimum functional requirements are not available.
Ireland	A National Smart Metering Plan is in place, the regulator (CER) started consultation process on a rollout strategy and functional requirements for electricity and gas (ongoing). A cost-benefit analysis will be available in March 2011 and will inform about the decision on a possible rollout.
Italy	Digital smart meters have been compulsory for all electricity providers since 2006. The Italian regulatory authority established minimum functional requirements and introduced incentives for the adoption of advanced metering features related to quality of supply.
Netherlands	Dutch Parliament adopted legal framework for voluntary installation of smart metering in November 2010. Customers may choose between four alternatives (from keeping

	conventional meters to full AMM). Privacy concerns dominated public discussions. Smart meters need option for "administrative off" and port for decentralised metering services (real-time feedback with data remaining in the house, etc.). An updated cost-benefit-analysis and functional requirements are available.
Norway	Regulation about mandatory hourly metering for all final customers with annual consumption over 100.000 kWh was introduced on the Jan 1st 2005. Any customer can require hourly metering of the electricity consumption from its local DSO if he covers the costs. A proposal for a full rollout and functional requirements was postponed in late 2009 in order to wait for European standards. In January 2011, the Ministry of Petroleum and Energy asked the Norwegian regulator to submit a proposal for earlier installation of smart metering technology in Central Norway by 2013 and a full rollout by 2016. A discussion document is published in February 2011.
Portugal	No legal framework for a mandatory rollout. In 2007, the regulator presented a meter substitution plan for the period 2010–2015 and a list of functional requirements. That plan is co-ordinated with Spain.
Spain	Spanish regulator forced Distribution companies to implement smart metering projects in a specific timeframe, establishing also a set of minimum functionalities that the implemented solution must cover. The ORDEN ITC/3860/2007 law established the obligation for DNOs to implement smart metering solution replacing all the meters before 2018.
Sweden	In 2003 the government passed a bill obligating the grid companies to a monthly meter reading for all electricity users by 2009. DSOs are responsible for metering. A cost-benefit-analysis resulted in net benefits of more frequent meter readings. Functional requirements are available.
United Kingdom	All aspects of utility metering have been unbundled and opened to competition. The supplier is responsible for metering and is required to contract with a meter asset provider, a meter operator and a data collector. In May 2007 the government set in train the requirement for energy suppliers to install smart meters in most businesses by 2012. In 2008 the government announced that it will require all households to have smart meters installed over the next 10 years. In July 2010, the government published the smart metering prospectus outlining the rollout strategy. Minimum requirements for meters and displays are proposed but not yet finally decided.

6. Experiences from the roll outs of smart meters

The situation varies very much between countries regarding:

- penetration of AMR
- functionality and
- requirements on functionality.

An overview report [11] shows a rough prediction of the smart metering penetration in each of the EU-15 countries in 2010 and 2020 and assesses the current interest in demand response (demand flexibility). Table 2 shows the conclusion with some updating. It is expected that in 2020 smart metering penetration will be about 100% in France, 60% in UK, 50% in Spain and Greece and 30% in Germany, if the current trends in regulatory, technical and market conditions continue.

Table 2. Status on Smart Metering developments in the EU-15 countries

	Smart metering penetration		Current interest in DR	Comments
	2010	2020 (moderate scenario)		
Austria	1 %	50 %	No	40000 smart meters installed, ongoing analysis by Utilities and the government
Belgium-Luxenbourg	1 %	80 %	No	Ongoing trials
Denmark	10 %	90 %	Yes	Small trials . Wind is the key issue . DR is viewed as a solution for compensating wind variability
Finland	50 %	90 %	Yes	Voluntary rollout of SM already in progress, estimated will reach 1,400,000 by 2010. Ministry of Labor and Economy has decided 80% SM rollout by 2014
France	1 %	100 %	Yes	A 300,000 smart meters pilot finished in 2011, target: 35 million smart meters in 2020
Germany	1 %	30 %	Yes	SM will take place if regulatory barriers are solved. if not Germany will be the last country with manual meters in the EU. Some Utilities estimate that SM penetration will be as low as 20-50% in 2020
Greece	1 %	50 %	No	However, looming power crisis ought to make DR seem more appealing
Ireland	5 %	100 %	No	DR pilots likely to happen. Wind development is a driver.
Italy	90 %	100 %	Yes	Utilities required to make TOU tariffs an option for all customers.
Netherlands	1 %	100 %	Yes	Heated discussion. 400000 households with smart meters 2012 – 2013. Large scale rollout from 2014.
Portugal	1 %	50 %	No	TOU tariffs and Direct Load Control are both being considered by the regulator. EdP is seriously involved in DR.
Spain	5 %	50 %	Yes	Wind is driving Spain to look at DR. 26 million smart meters by 2018, functional requirements defined
Sweden	100 %	100 %	Yes	TOU is already mandated
UK	1 %	100 %	Yes	OFGEM has it in the White Paper and has made free in home displays available through the network company to anyone who wants one. This is being fought as an unfunded mandate by the network companies

The most recent results of the 2008 FERC Demand Response and Advanced Metering Survey (2008 FERC Survey, [6]) in the USA indicate advanced metering penetration (i.e., the ratio of advanced meters to all installed meters) has reached about 4.7 per cent for the United States. This is a significant increase from 2006, when advanced metering penetration was less than one per cent.

Market penetration of advanced metering increased substantially in nearly all regions since 2006. Peninsular Florida had the largest increase, from less than one percent advanced metering penetration in 2006 to 10.4 per cent in 2008.

The 2007 FERC Demand Response Report identified 28 utilities that since 2005 had announced plans to deploy over 45 million advanced meters. Recent contracts to purchase advanced metering systems by Southern Company (4.2 million advanced meters), Alliant Energy (one million advanced meters), Duke Energy’s filing with the state of Indiana for an 800,000 advanced meter deployment bring planned deployments to nearly 52 million. These deployments are scheduled to take place over the course of the next five to seven years. The number is significant when one considers that there are totally 145 million meters in North America.

As explained below it can be expected the smart metering penetration in 2020 to be close to 100% in France, Spain, UK and in some other countries. In 28 October 2008, the UK government announced that it will mandate smart metering to all households with an indicative timetable that the rollout will be completed by 2020. In Spain in 2007 a government order was given that requires full penetration by 2018. Regarding Germany and Greece the development still seems highly uncertain and 50% penetration in Greece in 2020 seems rather optimistic.

UK

In UK the retail energy supply company (RESC) is responsible for meter purchase and for metering. Actual purchase may be by a meter asset provider. OFGEM (www.ofgem.org.uk) is responsible for the regulation of metering for gas and electricity. The number of smart meters in UK is small (some tens of thousands).

In UK the government has a goal that everybody has a smart meter and a display within the next ten years. They have initially been proposing that smart metering be introduced from 2010 and that meters should have a customer display.

The following information is included in [12]. In the 2008 Budget the Government has already announced its intention to legislate for a roll out of advanced metering to medium business over the next 5 years. The Government has 23 April 2008 proposed amendments to the energy bill. The amendments give Government the powers it needs to take the next steps on smart metering. The Government plans to take the final decision on a smart meter roll out to domestic and small business consumers as soon as possible after reception of the second report of the Energy Research Project trials which is expected in November 2008.

30 October 2008 the U.K. government [13] has announced that it will mandate smart meters for all households. This will result in as many as 47 million smart electricity and gas meters being rolled out nationwide. An indicative timetable a period of around two years is anticipated to resolve the issues and to design the full detail of the rollout, with a subsequent rollout to be completed by 2020.

In July 2010, the government published the smart metering prospectus outlining the rollout strategy. Minimum requirements for meters and displays are proposed but not yet finally decided.

Italy

In Italy ENEL has implemented smart metering to all of its 30 million electricity customers and several other distribution companies have followed. Requirements for full coverage AMR and minimum functionality have been established for the electricity meters in December 2006 by the regulatory order 292/06. All 36 million Italian electricity customers must be covered by smart metering by 2012. (All over 55kW customers must have smart metering by the end of 2008 and 95 % of 55kW or smaller customers by the end of 2011.) In July 2006 the Italian Energy Authority had given a consultation document [14] regarding the minimum functionality and performance of the electronic meters. The recommendation is based on a study of metering systems available on the market and the ENEL system seems to be compatible with almost all of these requirements. The requirements include: for three phase meters reactive energy in addition to active energy for all the meters, ability to record totalizers depending on the time of the day and day of the week for time of use price schemes, recording of hourly load profiles with a depth of at least 60-70 days, mains circuit breaker for direct demand control of single phase customers etc. and recording of quarter hourly peak for those meters that do not have a circuit breaker, security of data withdrawal, synchronization of meter clocks, remote periodic reading of consumption data for billing purposes, remote meter activation and closure, remote change of contracted power and price scheme, remote parametrization of meter, transmission of messages on the meter display, snapshots of the consumption data totalizers and quarter hourly peak power registers, meter display, and remote upgrades of the meter and data concentrator software. The Authority also felt that reading of hourly load profiles for dispatch purposes, through mandatory implementation in AMM systems, could gradually replace conventional load profiling for all LV customers, or for LV customers in a certain segment. Performance requirements for the above functionalities were also given. Starting 2012 all meters installed must meter energy bi-directionally. A consultation document of the minimum functional requirements for gas meters was published 9 June 2007.Compulsory remote metering and related functional and performance requirement are developed by the Authority.

Australia is preparing a full scale roll out for smart metering to its nearly 10 million energy customers. Detailed cost benefit analysis of smart metering and direct load control has been completed and is available from www.mce.gov.au. Costs and benefits of different functionalities and implementation alternatives are assessed. Based on the cost benefit analysis a recommendation for national minimum functionality is given. This includes an interface with a Home Area Network (HAN) that is expected to enable significant benefits via load control and energy efficiency improvement.

In California (USA) the electricity companies plan to complete full scale rollout of all customers by 2013 or sooner, depending on the company. **Ontario (Canada)** has given legislation that requires that in 2010 all customers have remotely communicating meters that meet certain requirements. Canadian distributor HydroOne has installed more than 1.2 million smart meters across Ontario (close to 100% of meters are installed), and as at June 2011, had transferred around 900 000 customers to TOU pricing. The Ontario Energy Board (Government) mandated that all HydroOne customers must be transferred to TOU pricing by October 2011.

7. Smart customers as a part of smart grid and smart metering

One part of smart customers is the customer behavior without automation, how to effect on the customers so that they consumes electricity in a rational way? Basically there are three main means to affect the electricity consumption habits:

- the indirect feedback in informative electricity bills showing the benefits of energy savings to customers and giving hints
- general education of customers and specific campaigns through different media like TV/radio, newspapers and internet
- the direct feedback from metering data either via internet or different types of home displays.

The last type of feedback is shortly discussed here.

7.1. The effectiveness of the feedback

The study [15] gives a basic summary of the literature on the feedback studies. Recently in [18] a short summary of the recent studies is given including

- Meta study on energy bill reductions due to information (Darby 2006)
  - Direct information (e.g., immediate) = 5-15%
  - Indirect treatments (billing detail) resulted in 0-10% reduction
  - In one case consumption increased
- Ontario Hydro Board –Direct
  - Information-only treatments ~225
  - Participants reduced electricity usage by 6.5% on average
- Newfoundland and Vancouver Residential Feedback Studies – Direct
  - Follow-up to Ontario Study (same in-home display device)
  - Newfoundland – 18% reduction in usage
  - Vancouver 2.6% reduction
- California State Pricing Pilot- Direct
  - Information treatment resulted in no significant difference in electric usage
- Milton Ontario Feedback Pilot – Indirect
  - 106 participants information-only treatment 2006-7
  - No discernible change in usage detected, but 64% said they took actions
- Prepaid Metering- Direct, Balance only
  - Salt River Project (SRP) - reports 12% average usage reduction among 55,000 (~5% of total) residential prepayment customers
  - Northern Ireland (Darby 2006) – 25% of residential consumers use prepay, and reportedly use, on average, use 3% less electricity
  - Woodstock Hydro (website) – 20-25% of residential customers use prepay and exhibit 15-20% reduction in electricity use

Figure 6 shows the summary of the electronic feedback studies. These study results suggest that there may be a large benefit to providing customer feedback on electricity consumption, especially if that feedback is direct and readily accessible on the premises. The results are surprisingly uniform, which might suggest that they are highly credible.

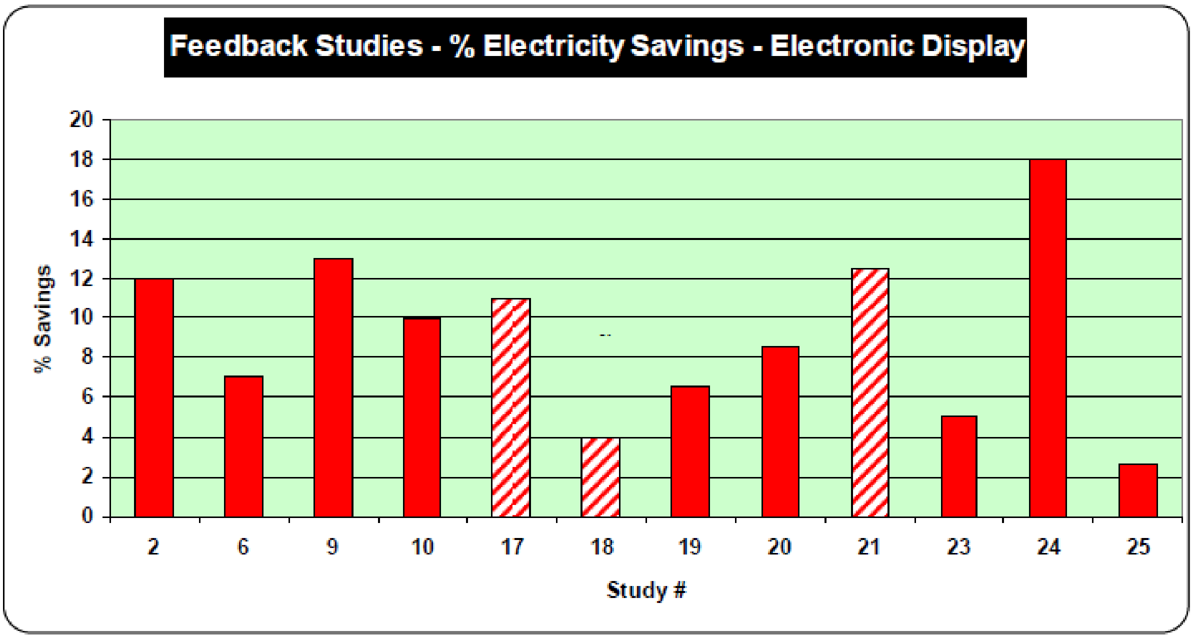


Figure 6. Electronic Display Electricity Savings [9]

In Figure 7 a summary of 36 studies based on different types of indirect and direct feedback in different countries is given. It includes also average results from the large study from UK (more detailed information from this can be found from [20].

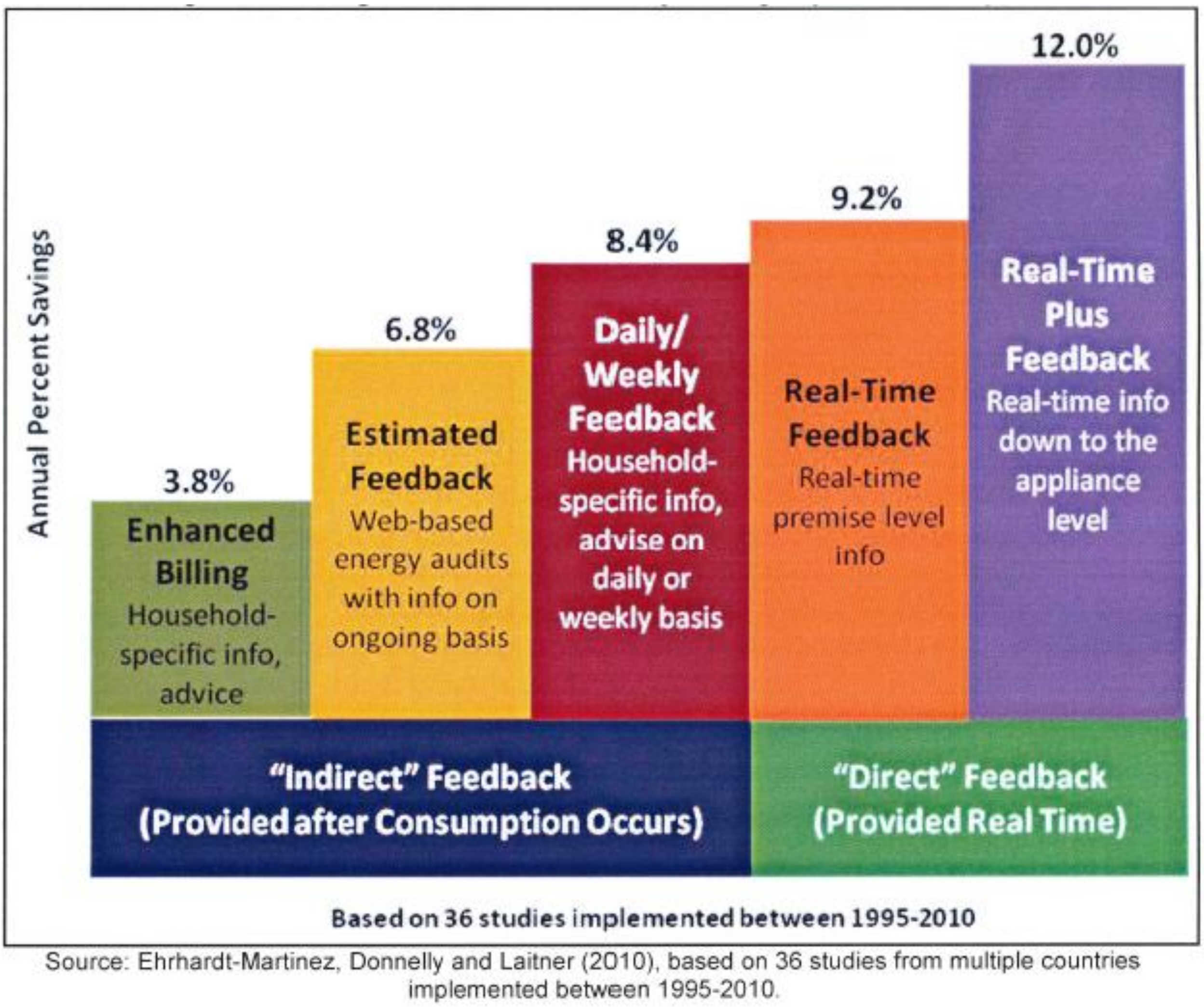


Figure 7. Summary of feedback studies [1]

7.2. Technologies of direct feedback

Direct feedback is a very active area for technology development. It is clear that a number of different options are being explored and the basic concepts have been set out below. It is not intended here to list all such devices but rather to pick those that illustrate different approached or novel features.

- **Consumption feedback via internet access.** One approach to energy feedback is to give customers access to the meter data held by the utility via a web site. This data can be displayed in a number of ways, such as in charts and tables. The data can also be linked to energy analysis software that allows the customer to enter the details of their energy usage and property. This in turn allows the web site to offer energy reduction advice and comparisons with other customers‟ usage. Many utilities currently offer energy analysis software for customers to model their usage. However, these can be very time consuming to fill in. The availability of smart meter data can simplify and speed this process.

- **Displays linked to meter data.** Numerous energy displays have now been developed and put on the market. A notable development in recent years has been the emergence of ZigBee enabled displays. Some of these are based on the new ZigBee energy profile and depend on the widespread installation of Zigbee enabled meters by US utilities. These displays can be offered by the utility or directly to the customer. This trend gives a glimpse of how the European market might develop if AMM meters were widely installed and were fitted with a standard local interface. It can be expected that the competing network protocols will seek to emulate the growth of the ZigBee device range.
- **Displays with non-meter data sources**. Despite this early work on displays linked to meters, in Europe the tendency has been for displays to be developed that are independent of the meter as there is currently poor local access to the data in the meter. A similar market is apparent in the US, where the local meters do not allow access to data. The majority of these displays utilise a split current transformer to measure the power flow at the meter. A few also measure voltage so that an accurate power value can be determined. These displays normally have a wireless link to a display. A number of the displays also link to computer packages to allow detailed analysis of the data.

The Energy Saving Trust has published a study dealing with the properties of displays taking into account the behavior of the average households [16]. It concludes that displays should have minimum functional requirements from the users' point of view including

1. The default display should include:

   - A clear analogue indicator of current rate of consumption
   - Current rate of consumption as a rate of spend in pounds per day (numeric)
   - Cumulative daily spend in pounds (numeric)

2. The display should offer the following options through interaction (by pressing a single button):

   - Spend in last seven days, day by day
   - Spend in last complete week
   - Spend in last complete month
   - Spend in last complete quarter

   The historic periods should match the utility's billing periods in order that the display is consistent with household bills.

3. The display should offer the option (by pressing a single button) of switching units from money to power, i.e. from pounds per day and pounds to kilowatts and kilowatt-hours. If interaction is not possible, current rate of consumption in kilowatts should form part of the default display.
4. The display should be mains-powered but have an internal battery to enable mobility in the home.

8. Present situation of smart metering in participating countries

In Annexes 1 – 5 a short description of the present situation in participating countries is given. In the following short summary on some aspects is given.

Austria

According to the new Electricity Act (ElWOG 2010), the Minister of Economy may introduce smart metering per decree, following a cost-benefit-analysis. The regulator may define functionalities and data requirements of a smart metering system. Current situation in Austria is that approx. 40.000 smart meters are installed, and it is planned that 80% of the customers will be equipped in 2020 according to the EU rules.

In the Austria consultation paper issued from E-Control the following requirements are listed which can enable DSM:

- Minimum of 4 registers for different tariffs per day (time of use).
- Communicate with at least 4 external meters - possible use as synergy for energy management systems
- Interface to external system

It is explicit stated, that the SM would not act as a gateway to home automation system to directly control external devices.

Finland

Currently, the number of the AMR meters is increasing rapidly in Finland, because almost all DSOs have AMR meter installation work ongoing. This is mostly due to the "Government Decree on settlement and measurement of electricity transactions (66/2009)". Based on the decree, at least 80 % of the customers have to be measured with AMR meters by 31st of December 2013. However, it is assumable that penetration will be almost 100 %, since most of the DSOs are installing AMR meters for all customers during their AMR installation programs. More than one million meters have been installed

Above mentioned government decree defines the minimum requirements and functionalities that energy meters have to meet.

- Customers' energy measurements have to be based on hourly measurements and remote readings
- The customers' energy meters have to be able to receive, transmit and execute load control commands
- Meters have to register begin and end times of the outages, which last more than three minutes

- Furthermore, based on the decree, the DSO is obliged to read its customers' hourly energy measurement data once a day, and its balance settlement has to be based on hourly measurements. Hourly energy measurement data has to be stored in DSO's database at least for six years. Similarly data concerning the outages has to be stored at least for two years.
- If customer requests so, DSO has to provide customer with AMR meter, which is equipped with standardised interface for real-time power consumption measurement. Although it is not said exactly, this can be interpreted so that customer has to be able to connect power consumption display to such meter
- Furthermore, it is defined that customer's measurement data has to be given for customer himself, without any payments. In practice, this can be realised by web-service, as has been already done by some companies.
- Moreover, there are some requirements for metering the distributed generation in the customer premises. If there is both generation and consumption, and main fuse is at maximum 3*63 A, one metering device can be used. However, it must be able to meter separately electricity fed to the network and electricity acquired from the network. It is not permitted to net the network input and output, but separate registers for these have to be used. In the case main fuse is over 3*63 A, there have to be separate meters for network input and output. Furthermore, in this case also consumption of own generation must be metered, which is the difference between generation of the electricity and output to the network.

France

ERDF was asked by the CRE (Energy Regulation Committee) to experiment an advanced smart meter counting system, based on recommendations made in the CRE's declaration of the 6th of June 2007. This LINKY pilot project consisted 300 000 meters and ended in March 2011. The CRE validated this experimentation. The deployment objective of smart meters is 35 million smart meters installed in 2020.

The results being positive, this project prefigures the national deployment of smart meter systems in France, though some points are still being discussed as, for instance, what kind of information and services suppliers should provide to their clients in order to help them reduce their consumption and at what price? By the end of 2011, there are still political discussions concerning who shall finance the system and who will own the meter (ERDF or local distribution managers).

On the basis of the experiments recommendations for counting and measuring devices are given. The counting and measuring devices must measure and record the load curve, the maximum power asked, the various quality characteristics of the electricity provided and must also support multiple index systems for price setting. Below are the details of the recommended measuring and recording parameters:

- Load curve (active power): time step of 10, 30, or 60min, with a minimum capacity of 2 months sliding memory with a 30min time step
- Maximum power asked: daily value with a sliding memory of 2 months
- Provided electricity quality: date and duration of short and long power break, date and duration of voltage excursion out of predefined limits, with a sliding memory of 2 years.
- Index system: 2 different indexes must be supported, 4 indexes for the prices and 10 indexes for the energy provision (regulated price market offer)

- The counting devices must also be able to display information such as: hourly seasonal index, instantaneous power, maximum power value. They must also include a limiting system (with a threshold set by step of 1 kVA).
- A bidirectional communication, to and from the upstream of the meter, and to the downstream of the meter: Upstream: the smart meter must allow the transfer of recorded data (energy flow and quality), the modification of its parameters (price calendars and subscribed power), and the possibility to command power breaks and power recovery.
- Downstream: there must be a controlled relay based on the price calendar of the distribution network manager or energy provider, and a data transfer interface for the user, which can transmit all the data collected to a display device or a remote device.

The Netherlands

The Dutch Government plans to roll out smart meters following Electricity Directive 2006/32 EC. The bill concerning the rollout was adopted in February 2011 and was followed by an Order in Council ("Algemene Maatregel van Bestuur" or "AMvB") which came into effect on January 1st 2012. This Order determines the functions of the Smart Meter on which the final standard should be based. The Grid Operators (GO's) in the Netherlands are responsible for the roll-out of smart meters, for both gas and electricity

There are currently about 8 million electricity meters and 7.1 million gas meters in the Netherlands. In a period starting in 2012 up to 2020, 80 percent of these meters will be replaced by smart meters

From the first of January 2012 the GO's will start with the small-scale rollout. During a two year period the GO's will be placing smart meters:

- In new domestic houses
- As part of regular replacements of old meters
- In case a customer requests a smart meter.

The GO's plan to install smart meters at 450.000 households in these 2 years. As most Dutch households are dual fuel consumers, this amounts to almost double that number in terms of actual meters. The large scale rollout is planned to start on January 1st 2014.

The current design of the smart meter in the Netherlands is based on the functional requirements and the global design as laid down in the NTA (Netherland technical Agreement). The functional specifications are detailed in the DSMR (the Dutch Smart Meter Requirements) to insure interoperability. Various versions of the DSMR have already been developed and published on the Netbeheer Nederland website.

An important decision that still has to be made for the large scale roll out is the communication technology that will be implemented. A number of options is being investigated, including GPRS/LTE, PLC and CDMA.

Spain

In 2007, since the publication of the "*Reglamento Unificado de Puntos de Medida"* (RD 1110/2007) and of the "*Orden Ministerial por la que se regula el control metrológico del estado"* (ITC/3022/2007), the regulatory framework for smart meters in the residential sector establish new functionalities to be implemented in the meters.

At the end of 2007, Spain approved the National Plan for Meters Substitution which involved the obligation for distribution companies to change 26 millions of meters in the residential sector in Spain for 2018. In addition consumers will pay around 15 % more each month for the smart meter rent since the moment that they have a new meter.

However the delay in the implementation of this plan has motivated a revision of milestones in the Orden IET/290/2012 maintaining the target of 26 millions of meters for 2018 but rescheduling the milestones.

The functional requirements for the smart meters in Spain are detailed in the RD 1110/2007 and in the ITC/3022/2007 and can be summarized as follows:

- End user information (demand, maximum power, TOU, information of load control…)
- Remote reading of power, energy consumed and other information (hourly measures)
- Verification of communications
- Verification of smart meter well functioning
- Event report (lack of voltage, overvoltage…)
- Remote synchronization of date and time
- Software y firmware update
- Remote control of contract power
- Management of TOU (at least with 6 periods) including dynamic updates of the tariffs
- Load management

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Appendix 1 Present situation of smart metering in Austria

A1.1. Policies related to the smart metering (support etc)

The legal framework for the introduction of smart metering for gas and electricity is given by:

- the 3. EU energy market package (RL/2009/72/EG for electricity and RL/2009/73/EG for gas) and the
- the Energy efficiency directive (RL/2006/32/EG)

It has been estimated that the electricity demand reduced by the introduction of SM will be about 3.5%. Reductions will be due to display of the current demand and the introduction of time-of-use tariffs (PwC 2010).

Current situation in Austria is that approx. 40.000 SM are installed, and it is planned that 80% of the customers will be equipped in 2020 (E-Control 2010a).

A1.2. Functional requirements

In the Austria consultation paper issued from E-Control the following requirements are listed which can enable DSM:

- Minimum of 4 registers for different tariffs per day (time of use).
- Communicate with at least 4 external meters - possible use as synergy for energy management systems
- Interface to external system

It is explicit stated, that the SM would not act as a gateway to home automation system to directly control external devices (E-Control 2009).

Consultation paper on innovative metering systems in Austria

In April 2007 E-Control posted a consultation paper entitled *"Einführung innovativer Messsysteme in Österreich"* (Introduction of Innovative Metering Systems in Austria) on its website (www.e-control.at). All market participants are entitled to make consultation submissions up to 15 June 2007.

E-Control welcomes the use of innovative metering systems in principle, and takes the view that the nationwide installation of such systems is already economically viable under current operating conditions (metering charges). In order to ensure that all market participants enjoy the benefits of these systems, E-Control recommends imposing the following minimum specification:

- Load profile recording;
- Bidirectional data communication;
- Multi-tariff functionality;

- Import and export metering;
- Power quality monitoring;
- Recording of supply interruptions;
- Centrally controllable maximum demand control and supply interruption;
- Display unit on the meter;
- Communication interface with an external display;
- Communication interface for the acquisition of data from external metering devices (e.g. gas, water or district heating).

In addition, metering data should be made accessible to authorized market participants at all times.

A1.3. List of research and demonstration projects and case studies to be included in the case study data base

Innovative Solutions to Optimise Low Voltage Electricity Systems: Power Snap-Shot Analysis by Meters (PSSA-M)

The existing low voltage networks in their traditional form are not rated for integrating a high number of renewable electricity producers. Today, the relevant decisions on connecting decentralized energy plants in low voltage networks are based on calculations related to estimated peak demands in single line sections. For this reason, during the planning, high safety margins have to be considered in addition. This is consequently restricting the capability of connecting distributed generation plants.

Therefore, the objective of the project ISOLVES:PSSA-M is to define and develop the required technical foundations to enable an increasing number of distributed energy feed-in opportunities in low voltage networks. For this purpose a method is developed to take an instantaneous image of the network, the so-called "Power Snap-Shot Analysis by Meters" (PSSA-M), and will be applied together with the smart meters to be adapted in the framework of the project.

Smart Efficiency – CO2 reduction based on automated efficiency and energy analyses for households via smart meters

Since the number of electrical devices in households is growing it is not possible for customers to recognize which of heir devices have a significant share of the whole electrical enegy consumption. The aim of this project is to develop an automated energy analysis-tool, which recognizes the major electrical devices out of the whole household energy consumption. Furthermore the user behavior will be analyzed automatically and possible energy savingsopportunities are shown in diagrams and tables. Additionally these data is monitored and assessed automatically.

The aim of this project is to develop a method for an automated energy analysis that provides customers visual advices for reducing, assessing and monitoring the electrical energy demand in their households. To realize this, the method of nonintrusive load monitoring and data-gathering from smart meters is used.

The basic idea of the method is to filter typical load profiles of the major electrical devices from the total electric load profile gathered by smart meters. So, devices like refrigerators and freezers, stoves, ovens, washing machines, dryers, dishwashers, electric water heaters and heating systems as well as the standby power consumption can be identified in detail.

SGMS – C2G: Consumer to Grid

This study investigates the way in which information about potential energy savings is best presented to the consumer in order to reduce energy consumption in the smart-grid. C2G aims at conducting basic research regarding if, how, when and what kind of energy feedback occupants need regarding a socio-demographic and cultural background. Various established and new forms of communication, combined with smart metering allow for investigating the impact, the sustainability and the handling of smart-grid enabled consumers. The expected results shall shed light on the most resource effective energy feedback methods for the human-in-the-loop in the smart grid.

These key factors will be obtained through user-centred methods such as interviews, questionnaires, focus groups, and experience probing. C2G will consider energy consumption information mediated through letters, emails, interactive online tools, mobile information, personal consultations, smart meters, energy feedback and ambient devices. Furthermore C2G will research what data and form of feedback occupants need to perceive, which are indirect, direct, historic, or disaggregated feedback. The influence of timing and pricing issues will be researched thoroughly and tested in a one-year trial phase as well.

Results from C2G will illustrate a roadmap of approaches and methods that should be applied regarding a social, demographical and cultural context. The roadmap shows practical approaches for our society and enables persons and organisations in charge to take the right steps for a future of sustained demand reduction without loss of comfort.

A1.4. Penetration scenarios

(PWC 2010])

Scenarios are:

• Scenario I: Penetration of gas and electricity smart meter 95% from 2011 to 2017.

• Scenario II: Penetration of gas and electricity smart meter 95%, electricity smart meter form 2011 to 2015 and gas smart meter from 2011 to 2017.

• Scenario III: Penetration of gas and electricity smart meter 95%, electricity smart meter from 2011 to 2017 and gas smart meter from 2011 to 2019.

• Scenario IV: Penetration of gas and electricity smart meter 80%, from 2011 to 2020.

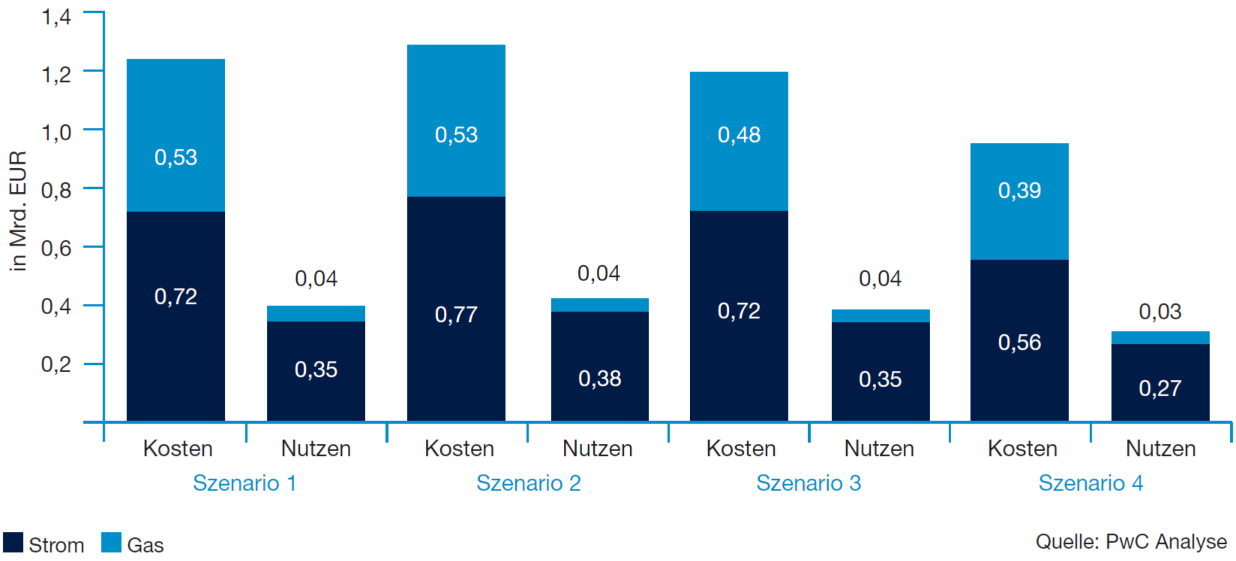

Figure A1 1. **Costs and Benefits of the introduction of smart meters for energy supplier, electricity and gas (PwC 2010)**

A1.5. References

PwC 2010: PwC Österreich, Studie zur Analyse der Kosten-Nutzen einer österreichweiten Einführung von Smart Metering, Juni 2010

E-Control 2010a: Leistungskatalog für fernauslesbare Smart Metering-Systeme im Bereich Strom, Öffentliches Konsultationspapier, Juni 2010.

E-Control 2009: Flächendeckende Einführung von intelligenter Zählergeneration (Smart Meter) bis 2016 realisierbar, Presse Information, März 2009

Appendix 2 Present situation of smart metering in Finland

Currently, the number of the AMR meters is increasing rapidly in Finland, because almost all DSOs have AMR meter installation work ongoing. This is mostly due to the "Government Decree on settlement and measurement of electricity transactions (66/2009)".

A2.1. Policies related to smart metering, functional requirements and displays

Above mentioned government decree defines the minimum requirements and functionalities that energy meters have to meet.

According to this decree, customers' energy measurements have to be based on hourly measurements and remote readings. In addition, the customers' energy meters have to be able to receive, transmit and execute load control commands. Furthermore, meters have to register begin and end times of the outages, which last more than three minutes. Furthermore, based on the decree, the DSO is obliged to read its customers' hourly energy measurement data once a day, and its balance settlement has to be based on hourly measurements. Hourly energy measurement data has to be stored in DSO's database at least for six years. Similarly data concerning the outages has to be stored at least for two years.

In addition to previous, decree also states that, if customer requests so, DSO has to provide customer with AMR meter, which is equipped with standardised interface for real-time power consumption measurement. Although it is not said exactly, this can be interpreted so that customer has to be able to connect power consumption display to such meter. However, DSO may charge customer for this kind of meter.

Furthermore, it is defined that customer's measurement data has to be given for customer himself, without any payments. In practice, this can be realised by web-service, as has been already done by some companies.

Moreover, there are some requirements for metering the distributed generation in the customer premises. If there is both generation and consumption, and main fuse is at maximum 3*63 A, one metering device can be used. However, it must be able to meter separately electricity fed to the network and electricity acquired from the network. It is not permitted to net the network input and output, but separate registers for these have to be used.

In the case main fuse is over 3*63 A, there have to be separate meters for network input and output. Furthermore, in this case also consumption of own generation must be metered, which is the difference between generation of the electricity and output to the network.

A2.2. Penetration scenarios

Based on previously discussed decree, at least 80 % of the customers have to be measured with AMR meters by 31st of December 2013. However, it is assumable that penetration will be 100 %, since most of the DSOs are installing AMR meters for all customers during their AMR installation programs.

Appendix 3 Present situation of smart metering in France

A3.1. Introduction: a context defined by regulations

The European directive 2009/72/CE promotes smartmeter deployment, fixing a target of 80% of clients equipped until 2020.[1]

The article 19 of the law of February 10th 2000 and the article 13 of the law of august 09th 2004 provide that distribution network manager are responsible of the counting necessary and define their role.

The article 4 of the law of February 10th 2000 specifies that the counting devices set up by the distribution network manager must allow the energy providers to propose to the clients different prices depending of the period of the year or the day and encourage the network users to limit their consumption during the periods of global high consumption.[2]

The Energy Regulation Committee (CRE) made different declarations about smartmeter counting on the 5th of July 2001, the 29th of January 2004 and the 6th of June 2007.[3]

In France, 95% of the electricity distribution is carried out by the company ERDF[4], concessionaire of the granting authorities (often commune grouped together in an energy trade union).

The other 5% are carried out by local distribution companies (Entreprise Locale de Distribution, ELD) that are most of the time owned as a majority by the local communes.

ERDF was asked by the CRE to experiment an advanced smartmeter counting system, based on recommendations made in the CRE's declaration of the 6th of June 2007.[5]

This pilot project ended in March 2011. The results being positive, this project prefigures the national deployment of smartmeter systems in France, though some points are still being discussed as, for instance, what kind of information and services suppliers should provide to their clients in order to help them reduce their consumption and at what price?

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[1] Official Journal of the European Union

[2] CRE's deliberation of the 11th of February 2010 about the terms of realisation and evaluation of the ERDF experiment about low voltage counting device evolution, page 1

[3] CRE's deliberation of the 11th of February 2010 about the terms of realisation and evaluation of the ERDF experiment about low voltage counting device evolution, page 1

[4] ERDF's website

[5] CRE, evaluation of the LINKY experiment folder, June 2011, page 5

A3.2. Recommendations for functionality and performance of advanced counting systems

These recommendations [6](reference for the entire section) concern:

- The counting and measuring devices
- The associated teleprocessing device

The following information below is given by the CRE

A3.2.1 Counting and measuring devices

The counting and measuring devices must measure and record the load curve, the maximum power asked, the various quality characteristics of the electricity provided and must also support multiple index systems for price setting.

Below are the details of the recommended measuring and recording parameters:

- Load curve (active power): time step of 10, 30, or 60min, with a minimum capacity of 2 months sliding memory with a 30min time step

- Maximum power asked: daily value with a sliding memory of 2 months

- provided electricity quality: date and duration of short and long power break, date and duration of voltage excursion out of predefined limits, with a sliding memory of 2 years.

- Index system: 2 different indexes must be supported, 4 indexes for the prices and 10 indexes for the energy provision (regulated price market offer)

The counting devices must also be able to display information such as: hourly seasonal index, instantaneous power, maximum power value. They must also include a limiting system (with a threshold set by step of 1 kVA).

A bidirectional communication, to and from the upstream of the meter, and to the downstream of the meter:

- Upstream: the smartmeter must allow the transfer of recorded data (energy flow and quality), the modification of its parameters (price calendars and subscribed power), and the possibility to command power breaks and power recovery.

- Downstream: there must be a controlled relay based on the price calendar of the distribution network manager or energy provider, and a data transfer interface for the user, which can transmit all the data collected to a display device or a remote device.

[6] CRE's deliberation of the 11th of February 2010 about the terms of realisation and evaluation of the ERDF experiment about low voltage counting device evolution, Appendix n° 1 – Criteria hold by the CRE for evaluating the experiment of an advanced counting system by ERDF, page 3 to 5

A3.2.2 The teleprocessing system

The teleprocessing system must have a sufficient capacity which permits to collect data every day.

It must permit to command at distance power breaks and power recoveries, to modify the subscribed power value, to modify the price calendar.

A mobile peak demand must be able to be taken into account, as well as the corresponding notice from the provider to the network manager, at the latest at 16h the day before.

It must also support the various provider's price calendar offers and the providers own supply offers systems, limited in time and quantity.

A user access to all the data recorded and measured by the meter, and so for the past 2 years, must be available.

A3.3. ERDF's advanced counting system pilot project: the LINKY

A3.3.1 The LINKY project's context

ERDF carried out the first pilot project on advanced counting devices.

It consisted in the installation of 300 000 smartmeters in 2 regions, an urban one (Lyon) and a rural one (Indre et Loir). This experiment occurred between 2009 and March 2011.

A3.3.2 LINKY project's results

The projects results [7](reference for the entire section) are globally positive: the greatest part of the tested functionality was validated, as well as the performances, which led to the validation of the experiment and the decision to pursue its deployment at a national level.

Indeed, the experiment has validated the expected capability to inform the end user, to improve the electricity market functioning and improve the costs control by the network managers.

A3.3.2.1 Capability to inform the end user

In terms of information given to the end user, the experiment validated that the LINKY can effectively do everything that is asked in section II-A above.

The device also guarantees the protection and confidentiality of the date recorded

However, a few points must be looked at closer:

- the impossibility to send a monthly bill on real energy consumption due to an actual insufficient information system
- the limited visibility of the display of the device

[7] CRE, evaluation of the LINKY experiment folder, June 2011, Chapter II Counting device's functionalities

Note that most meters in France are not installed into the houses or flats, but next to the street. That is why consumer's organizations and the Environment and Energy Agency (ADEME) promote the deployment of in-home-displays or other information systems.

A3.3.2.2 Capability to improve the functioning of the market

In terms of improvement of the functioning of the market, the experiment has validated that the LINKY

- gives the possibility to the provider to choose his price calendar independently of the TURPE (Use Price of the Public Electricity Network) price calendar
- make available 4 indexes for the TURPE and 10 indexes for the supply
- permits the provider to make limited quantity offers (by using power break or power decrease distance commands)
- integrates a telecontrolled switch, with a 1 kVA step adjustable threshold
- permits to command the dry contact of the meter by mean of the provider's price grid
- is compatible with the already existing and installed devices

The only restrictions are that the experiment did not test the tele-payment, neither the recording of power overrun. However these options de not seem expedient after discussion with the different actors.

A3.3.2.3 Capability to contribute to the network manager's cost control

The experiment has validated that the LINKY:

- participates in the supply quality control: it implements the voltage level monitoring, the short and long power break occurrences monitoring, and can memorizes the recorded data for a minimum of 2 years (sliding memory)
- minimizes the running costs by permitting various operations: periodic measurement, power subscription modification, put in operation and termination of electricity access, power breaks and recoveries, specific operation to the new competitive market (change of energy provider, change of price calendar)

A3.3.2.4 Capability to contribute to energy control and to reduce the peak demand

The experiment has shown that the tested advanced counting device helped in controlling the energy demand and in reducing the carbon emissions:

- renewable energies: allowing no limitation on injected power and counting the reactive power absorbed by production installations
- recording of the instantaneous subscribed power overrun and of the maximum asked power
- independent price grids and mobile peak price setting
- transmission to users of the different price grid signals
- allowing the connection of other information and control devices

The counting device permits to reduce the load demand but not by a power reduction. This additional complex option has not been asked since a reduction of asked power (instead of a simple power cut) needs that the user is equipped of an energy control device or needs the users' presence in order to understand the power cut. Those conditions have been judged too restrictive to be set up.

A3.4. The planned deployment of smartmeters

A3.4.1 Smartmeter deployment

ERDF plans on the deployment of 35 millions of LINKY smartmeters on the 95% of the distribution network that ERDF manages.

ERDF plans on two targets:

- a first target of a deployment of 7 millions of smartmeters between 2013 and 2015, using G1 communication protocol
- a second target of a deployment of 28 millions of smartmeters during four years (7 millions per year), using G3 communication protocol

Only G1 communication protocol has been tested so far. G1 is a Frenche version of the BPL protocol. G3 is based on internet IP addressing system, but is not mature yet.

A3.4.2 The deployment technical and economical studies

Here is the presentation of the technical and economical study directly issued from the CRE's report:

The CRE committed to Capgemini Consulting the realisation of a technical and economical study analysing the costs and profits of the LINKY project at the distribution network manager level.

This study was conducted on the 2011-2038 period, 2038 corresponding to the end-of-life of the smartmeters deployed during the massive deployment stage.

The net present value (VAN) of the LINKY project is evaluated by the difference between the costs and the profits associated to the realisation of the project and the ones associated to its non-realisation ("business as usual"). The estimated earnings are the avoided investments and functioning costs, while the additional costs are the costs brought by conducting the project.

The price of electricity being one of the most important parameter of the analysis, Capgemini Consulting developed 2 price evolution scenarios:

- 1: annual average increase of 2.3% on the 2010-2020 period, 1.8% afterwards
- 2: annual average increase of 5.75% on the 2010-2020 period, 1.8% afterwards

On the basis of the hypothesis made by Capgemini Consulting, the VAN of the LINKY project for the distribution network activity is almost at equilibrium in scenario 1 (€ +0.1 millions) and positive in scenario 2 ((€ +0.7 millions). The following table describes the content of the VAN

(in Billion of €)	Scenario 1	Scenario 2
Gross investments*	**-3,8**	**-3,8**
Meter (equipment and installation)	**-3,0**	**-3,0**
Hub (equipment and installation)	**-0,5**	**-0,5**
Information systems	**-0,3**	**-0,3**
Incomes on investments expenditures due to renewal of existing meters	**+1,5**	**+1,5**
Incomes on « network » investments expenditures	**+0.1**	**+0.1**
Incomes on operation expenditures related to losses	**+1,2**	**+1,8**
Incomes on operation expenditures related to technical maintenance	**+1,0**	**+1,0**
Incomes on operation expenditures related to data collecting	**+0,7**	**+0,7**
Other incomes on operation expenditures	**+0,1**	**+0,1**
Additional costs due to the operation of the advanced counting system	**-0,7**	**-0,7**
Total	**+0,1**	**+0,7**

By taking slightly different hypothesis than ERDF (actualization rate, wage evolution rate), Capgemini evaluates the total gross investment to € 3.8 billions. ERDF evaluates it at € 4.3 billions.

This evaluation leans upon a massive deployment which would start in 2013 and would end end of 2018, with 90% of the counting devices being advanced counting devices (the resting 10% being equipped in advanced counting devices on the 2019-2028 period). About the broadband over power line (BPL) technology, the years 2013 to 2015 would see the deployment of about 7 millions of counting devices (5.1 millions from 2013 to 2014) and 75 000 hubs equipped of a "BPL G1" technology. And during the years 2015 to 2018, the deployment of 28 millions of counting devices and 345 000 hubs equipped with "BPL G3" technology would occur.

A3.4.3 The CRE's recommendations for carrying out the LINKY's deployment

The CRE validated the system. It gave different recommendations concerning the choice of the communication technology (BPL G1 or G3), the information for the user based on the system's counting/measuring data, the preparation of the deployment (communication, information system functioning, preliminary commercial experiment).

The CRE recommends launching the deployment with the CPL G1 technology, which is sufficient for the functionalities required by the LINKY system, but aims on the CPL G3 technology deployment on the long run.

The CPL G3 technology should bring new functionalities to the network manager (joint observability of high voltage and low voltage network for example).

A3.5. Conclusion

The LINKY has proved, through experimentation and validation, to be an adapted advanced counting system in preparation for the national deployment of smartmeters.

300 000 LINKYs have already been installed by ERDF and experimented. The CRE (Energy Regulation Committee) validated this experimentation. The deployment objective of this smartmeters is 35 million smartmeters installed in 2020.

This smartmeter comes with developed functionalities which permit the integration of a DSM strategy. Load profile access, targeted power cuts, advanced price setting such as DSM mobile peak price setting. But consumer consumption information should still be improved.

Of course it already puts up with the existing strategies such as heater control or time-of-day rates.

By the end of 2011, there are still political discussions concerning who shall finance the system and who will own the meter (ERDF or local distribution managers)

Appendix 4 Present situation of smart metering in the Netherlands

A4.1. Background

The Dutch Government plans to roll out smart meters following Electricity Directive 2006/32 EC. The bill concerning the rollout was adopted in February 2011 and was followed by an Order in Council ("Algemene Maatregel van Bestuur" or "AMvB") which came into effect on January 1st 2012. This Order determines the functions of the Smart Meter on which the final standard should be based.

There are currently about 8 million electricity meters and 7.1 million gas meters in the Netherlands. In a period starting in 2012 up to 2020, 80 percent of these meters will be replaced by smart meters.

A4.2. Responsibilities

The Grid Operators in the Netherlands are responsible for the roll-out of smart meters, for both gas and electricity. The Netherlands is separated into 9 different grid operators, of which 3 large GO's (e.g Alliander, Enexis en Stedin) and six smaller ones.

The grid operators have been working together for some years in the area of smart meters and have developed a joint organization called "Netbeheer Nederland" which manages a growing range of projects. At the start it was only intended to develop a joint set of specifications, the Dutch Smart Meter Requirements (DSMR). Nowadays, the scope has widened to area's such as purchasing, testing, communication, privacy & security to name a few.

A4.3. Rollout

The Grid Operators made clear agreements with the government in the Netherlands regarding the planning of the rollout and the functionalities of the meters.

From the first of January 2012 the GO's will start with the small-scale rollout. During a two year period the GO's will be placing smart meters:

- In new domestic houses
- As part of regular replacements of old meters
- In case a customer requests a smart meter.

The GO's plan to install smart meters at 450.000 households in these 2 years. As most Dutch households are dual fuel consumers, this amounts to almost double that number in terms of actual meters.

Dutch GO's already have significant experience with smart meters. At the time of the start of the small scale rollout, GO's already operated a sizeable number of "legacy meters" – roughly 270.000 E and 230.000 G meters.

Up to this moment, pilot projects have used both GPRS and PLC for communication. However, PLC has a number of drawbacks: interoperability and performance. At this point, PLC standardization is insufficient to meet Dutch requirements. In addition, PLC requires street by street rollout which doesn't fit with the demands of the small scale rollout. For this reason, GPRS will be used during the small scale rollout.

During the small scale roll-out two evaluation moments are planned. These evaluation moments focus on two aspects:

- Assess whether the energy efficiency targets regarding smart meters are actually being achieved
- Monitor the efficiency of the roll-out

In order to measure the effect of smart meters on energy efficiency, a number of pilot projects are being carried out. These projects make use of several types of feedback mechanisms such as in-home displays that are connected to the smart meter.

The large scale rollout is planned to start on January 1st 2014.

A4.4. Design

The current design of the smart meter in the Netherlands is based on the functional requirements and the global design as laid down in the NTA (Netherland technical Agreement). The functional specifications are detailed in the DSMR to insure interoperability. Various versions of the DSMR have already been developed and published on the Netbeheer Nederland website. As Figure A4 1 shows, the DSMR architecture uses P1, P2, P3 and P4 ports to communicate. Note that the gas meter connects to the network via the electricity meter (P2).

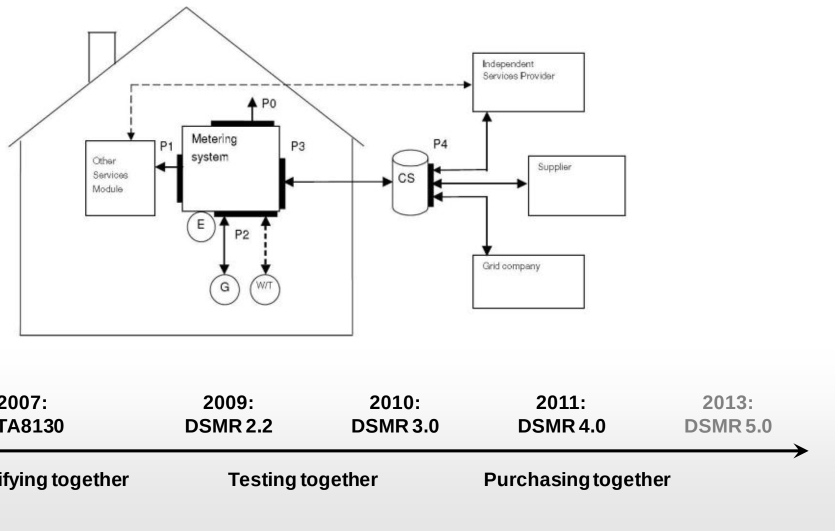

Figure A4 1. DSMR High Level Architecture

The Grid Operators and the Dutch Legislator have agreed to plan 3 releases of the smart meter:

1. The current meter, DSMR version 2.2, which can be installed until the end of 2012.
2. The next release will be the DSMR4.0 meter. This meter must be compliant with the Dutch Privacy& Security requirements version 1.5. In addition, temperature correction for gas must be implemented.
3. The final version (DSMR5.0) must be completely in line with the legislation. The most important requirement in this release is that the meter must be modular. The DSMR5.0-meter will be used during the large scale roll out.

The overall phasing regarding roll-out, legislation and standardization is shown in Figure A4 2 below.

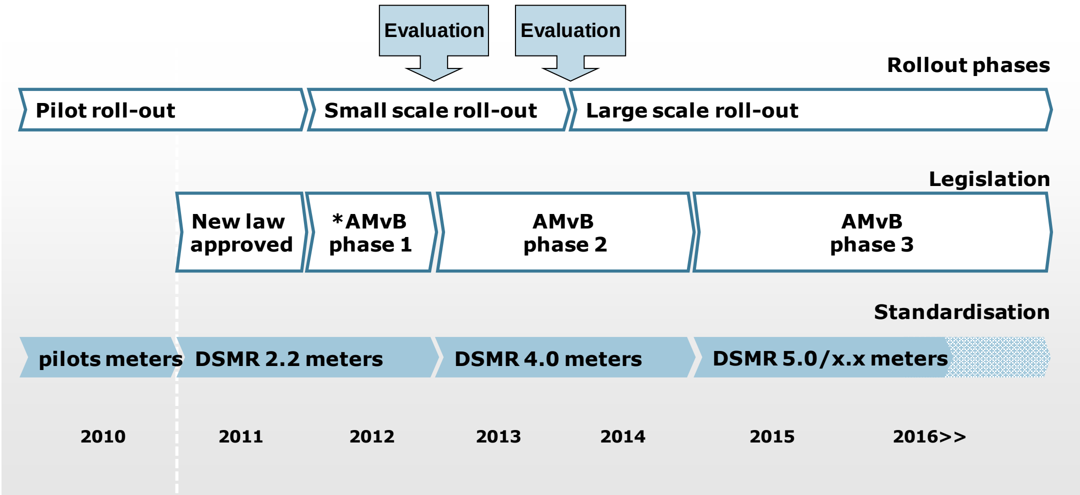

Figure A4 2. Legislation vs DSMR versions

An important decision that still has to be made for the large scale roll out is the communication technology that will be implemented. A number of options is being investigated, including GPRS/LTE, PLC and CDMA.

Appendix 5 Present situation of smart metering in Spain

It is important to note the key role that the "smart grid" has in the implantation of demand side management measures, defining "smart grid" as the process "to transform the functionality of the present electricity transmission and distribution grids so that they are able to provide a user-oriented service, enabling the achievement of the 20/20/20 targets and guaranteeing, in an electricity market environment, high security, quality and economic efficiency of electricity supply" (ENTSOE).

Therefore the installation of smart meters that allow the smart measures and management will be a key role in the path of the development of demand side management measures in Spain. Additionally, smart meters could play a relevant role in the profiling system for settlements.

A5.1. Regulatory framework

In 2007, since the publication of the "*Reglamento Unificado de Puntos de Medida*" (RD 1110/2007) and of the "*Orden Ministerial por la que se regula el control metrológico del estado*" (ITC/3022/2007), the regulatory framework for smart meters in the residential sector establish new functionalities to be implemented in the meters.

At the end of 2007, Spain approved the National Plan for Meters Substitution which involved the obligation for distribution companies to change 26 millions of meters in the residential sector in Spain for 2018. In addition consumers will pay around 15 % more each month for the smart meter rent since the moment that they have a new meter.

However the delay in the implementation of this plan has motivated a revision of milestones in the Orden IET/290/2012 maintaining the target of 26 millions of meters for 2018 but rescheduling the milestones.

Figure A5 1. Spanish Smart Meters Substitution Plan

A5.2. Functional requirements in Spanish smart meters

The functional requirements for the smart meters in Spain are detailed in the RD 1110/2007 and in the ITC/3022/2007 and can be summarized as follows:

- End user information (demand, maximum power, TOU, information of load control…)
- Remote reading of power, energy consumed and other information (hourly measures)
- Verification of communications
- Verification of smart meter well functioning
- Event report (lack of voltage, overvoltage…)
- Remote synchronization of date and time
- Software y firmware update
- Remote control of contract power
- Management of TOU (at least with 6 periods) including dynamic updates of the tariffs
- Load management

A5.3. Communications

An Advanced Metering Infrastructure (AMI) is not only a smart meter but also the different communications infrastrucutres and protocols. (AMI implies an evolution from the Automatic Meter Reading, AMR, including new functionalites and advances services)

Normally the communication infrastructure for an AMI system is composed by three big segments:

- LAN (Red Local). This segment connects the smart meters with the communications Gateway.
- WAN Acces (Red de Acceso). This part is the communication system between the communications Gateway and the Data Concentrator Unit (DCU) wich aggregates information from different local areas and communicates with the management center.
- WAN (Red Troncal). Connects the different DCU with the Central Management System and also connects the different players

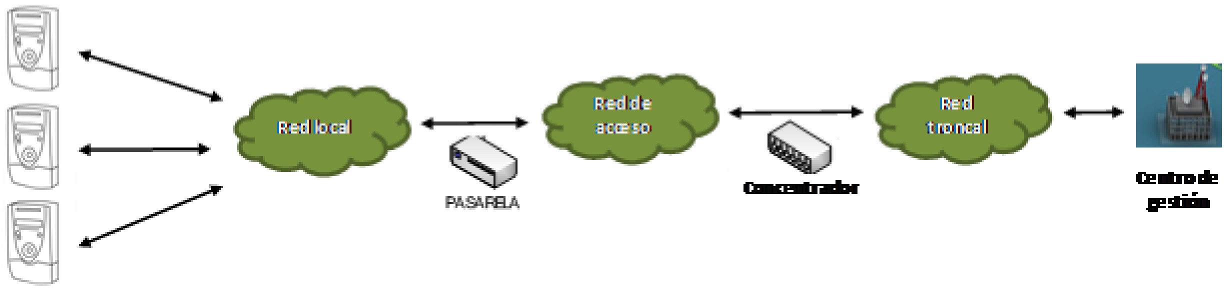

Figure A5 2. ***AMI basic scheme***

The communication system is essential in the AMIs because it can be a enabler or a barrier in the implementation of advanced Demand Side Management measures and services. In Spain there is the example developed within the GAD Project which communications architecture is shown in the next figure.

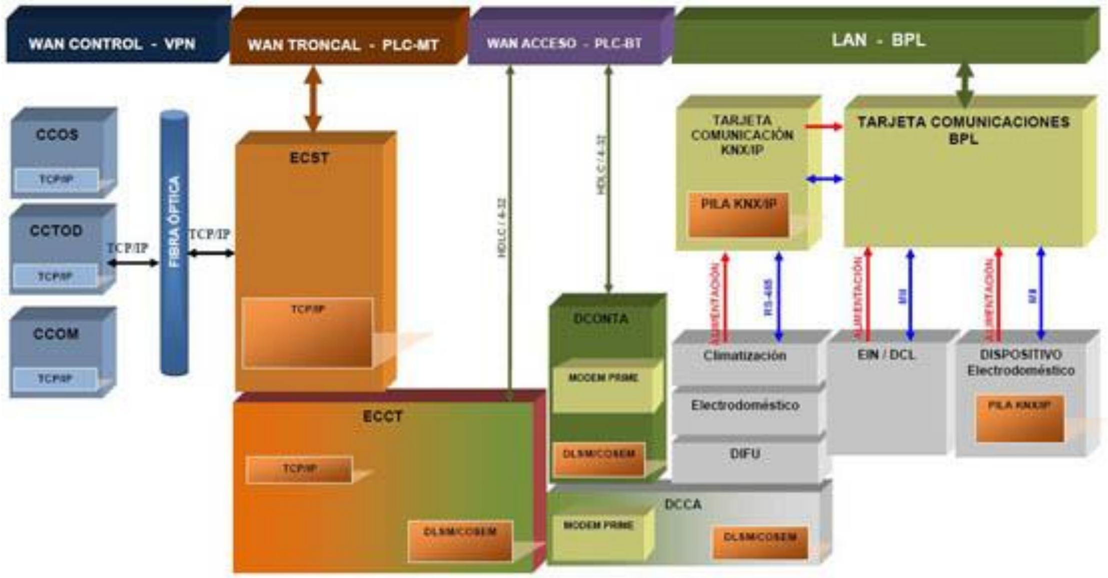

Figure A5 3. ***GAD Project* communication *architecture.***

It is important to mention that in parallel with the installation of smart meters distributors are developing Smart Meters systems in order to have a complete telemeasuring and telemanagement of the meters installed. The Spanish Plan fixed 2014 as dealing to have this telemanagement and telemeasuring systems

A5.4. National projects

In addition to European projects in which Spain is involved there are other many national projects regarding smart meters. Here we describe two of them: the Gad Project and the PRICE project

- ***GAD Project***

    - *Participants:* Leader: IBERDORLA. ITC partners: GTD SISTEMAS DE INFORMACIÓN, S.A., SIEMENS, S.A., DISTRIBUIDORA INDUSTRIAL DE AUTOMATISMOS Y TELETRANSMISIÓN, S.A., ZIV MEDIDA, S.L., ERICSSON ESPAÑA, S.A. Energy partners Energy Area, Grupo GAS NATURAL, RED ELÉCTRICA DE ESPAÑA. Capital godos area: FORESIS, FAGOR ELECTRODOMESTICOS, BSH ELECTRODOMESTICOS, ALTRA Corporación empresarial, ORBIS tecnología eléctrcia and 14 Spanish Research *centers **(**Centro Andaluz de Innovación y Tecnologías de la Información y las Comunicaciones, Centro de Desarrollo de las Telecomunicaciones de Castilla y León, Ikerlan (Centro de Investigaciones Tecnológicas), Instituto de Tecnología Eléctrica, Universidad de Alcalá de Henares, Universidad Politécnica de Madrid, Universidad de Zaragoza, Centre Tecnològic de Telecomunicacions de Catalunya, Fundación Labein, Instituto de Ingeniería del Conocimiento,Instituto Tecnológico de Aragón, Universidad de Málaga, Universidad Pontificia de Comillas - Instituto de Investigación Tecnológica, Universitat Ramon Llull)*

- *Time period:* 2007 to 2010 (budget 23 M€)

- *Project Description (objectives/goals):* The ultimate aim of the GAD Active Demand Side Management Project was to optimise electrical energy consumption and the costs associated, while meeting consumer needs and maintaining quality standards. Implementing this project generated the knowledge necessary to standardise different consumption patterns and provide users and final consumption items with signs that would allow them to freely decide based on prices, energy source, environmental impact, etc, in the case of the former, and to stand at the most appropriate level of consumption -providing user consent- in the case of the latter. Furthermore, the new management mechanisms will require the corresponding network automation, which may result in an improvement of the quality of the electrical supply.

- *Scope of the demonstration:* 1 house full equipped with smart meters and appliances, TSO, DSO and retailer management systems developed.

- ***PRICE Project***

  - *Participants:* Leader: IBERDORLA and Grupo GAS NATURAL. Partners: RED ELÉCTRICA DE ESPAÑA, INDRA, FAGOR ELECTRODOMÉSTICOS, ZIV I+D. ITE IKERLAN.

  - *Time period:* 2011 to 2013 (budget 34 M€)

  - *Project Description (objectives/goals):* This Project has a wide scope including all the aspects related to integration of distributed resources. Regarding DSM the goal is to develope a monitoring and management system (for DSO, TSO and retailer) that take into account consumers with smart meters (installed within the context of the National Smart meters substitution Plan)

  - *Size of the demonstration:* 500.000 homes with smart meters, 50 houses full equipped with smart meters and appliances.

Appendix 6 Overview of the IEA Demand-Side Management Programme

IEA Demand Side Management Programme

The Demand-Side Management (DSM) Programme is one of more than 40 co-operative energy technology programmes within the framework of the International Energy Agency (IEA).The Demand-Side Management (DSM) Programme, which was initiated in 1993, deals with a variety of strategies to reduce energy demand. The following 16 member countries and the European Commission have been working to identify and promote opportunities for DSM:

Austria	Netherlands
Belgium	Norway
Canada	New Zealand
Finland	Spain
France	Sweden
India	Switzerland
Italy	United Kingdom
Republic of Korea	United States

Sponsors: RAP

Programme Vision during the period 2008 - 2012: Demand side activities should be active elements and the first choice in all energy policy decisions designed to create more reliable and more sustainable energy systems

Programme Mission: Deliver to its stakeholders, materials that are readily applicable for them in crafting and implementing policies and measures. The Programme should also deliver technology and applications that either facilitate operations of energy systems or facilitate necessary market transformations

The Programme's work is organized into two clusters:

- The load shape cluster, and
- The load level cluster.

The 'load shape" cluster will include Tasks that seek to impact the shape of the load curve over very short (minutes-hours-day) to longer (days-week-season) time periods. Work within this cluster primarily increases the reliability of systems. The "load level" will include Tasks that seek to shift the load curve to lower demand levels or shift between loads from one energy system to another. Work within this cluster primarily targets the reduction of emissions.

A total of 24 projects or "Tasks" have been initiated since the beginning of the DSM Programme. The overall program is monitored by an Executive Committee consisting of representatives from each contracting party to the Implementing Agreement. The leadership and management of the individual Tasks are the responsibility of Operating Agents. These Tasks and their respective Operating Agents are:

Task 1 International Database on Demand-Side Management & Evaluation Guidebook on the Impact of DSM and EE for Kyoto's GHG Targets - *Completed*
Harry Vreuls, NOVEM, the Netherlands

Task 2 Communications Technologies for Demand-Side Management - *Completed*
Richard Formby, EA Technology, United Kingdom

Task 3 Cooperative Procurement of Innovative Technologies for Demand-Side Management – *Completed*
Dr. Hans Westling, Promandat AB, Sweden

Task 4 Development of Improved Methods for Integrating Demand-Side Management into Resource Planning - *Completed*
Grayson Heffner, EPRI, United States

Task 5 Techniques for Implementation of Demand-Side Management Technology in the Marketplace - *Completed*
Juan Comas, FECSA, Spain

Task 6 DSM and Energy Efficiency in Changing Electricity Business Environments – *Completed*
David Crossley, Energy Futures, Australia Pty. Ltd., Australia

Task 7 International Collaboration on Market Transformation - *Completed*
Verney Ryan, BRE, United Kingdom

Task 8 Demand-Side Bidding in a Competitive Electricity Market - *Completed*
Linda Hull, EA Technology Ltd, United Kingdom

Task 9 The Role of Municipalities in a Liberalised System - *Completed*
Martin Cahn, Energie Cites, France

Task 10 Performance Contracting - *Completed*
Dr. Hans Westling, Promandat AB, Sweden

Task 11 Time of Use Pricing and Energy Use for Demand Management Delivery- *Completed*
Richard Formby, EA Technology Ltd, United Kingdom

Task 12 Energy Standards
To be determined

Task 13 Demand Response Resources - *Completed*
Ross Malme, RETX, United States

Task 14 White Certificates – *Completed*
Antonio Capozza, CESI, Italy

Task 15 Network-Driven DSM - *Completed*
David Crossley, Energy Futures Australia Pty. Ltd, Australia

Task 16 Competitive Energy Services
Jan W. Bleyl, Graz Energy Agency, Austria
Seppo Silvonen/Pertti Koski, Motiva, Finland

Task 17 Integration of Demand Side Management, Distributed Generation, Renewable Energy Sources and Energy Storages
Seppo Kärkkäinen, Elektraflex Oy, Finland

Task 18 Demand Side Management and Climate Change - *Completed*
David Crossley, Energy Futures Australia Pty. Ltd, Australia

Task 19 Micro Demand Response and Energy Saving - *Completed*
Barry Watson, EA Technology Ltd, United Kingdom

Task 20 Branding of Energy Efficiency
Balawant Joshi, ABPS Infrastructure Private Limited, India

Task 21 Standardisation of Energy Savings Calculations
Harry Vreuls, SenterNovem, Netherlands

Task 22 Energy Efficiency Portfolio Standards
Balawant Joshi, ABPS Infrastructure Private Limited, India

Task 23 The Role of Customers in Delivering Effective Smart Grids
Linda Hull. EA Technology Ltd, United Kingdom

Task 24 Closing the loop - Behaviour change in DSM, from theory to policies and practice
Sea Rotmann, SEA, New Zealand and Ruth Mourik DuneWorks, Netherlands

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Also, visit the IEA DSM website: http://www.ieadsm.org