Definition of Smart Metering and Applications and Identification of Benefits

Project: European Smart Metering Alliance

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CONTENTS

1. EXECUTIVE SUMMARY

European Smart Metering Alliance (ESMA) in an Intelligent Energy Europe project that collects and disseminates information improving energy efficiency via smart metering. ESMA deliverable D3 defines smart metering and its applications for the ESMA project.

Meters have been called smart since the introduction of static meters that included one or more microprocessors. Already about 15 years ago for big customers there were meters that met the present definitions of smart meter. Mass application of smart meters to small customers is still a rather new and developing field, because it requires not only low cost smart meters, but also systems that can manage both the meters and the large amounts of metered data as well as provide metered data to various applications.

There is no universal definition of smart metering. Thus for the context of ESMA the following definition was developed:

Smart metering has the following features:

- **Automatic processing, transfer, management and utilisation of metering data**
- **Automatic management of meters**
- **2-way data communication with meters**
- **Provides meaningful and timely consumption information to the relevant actors and their systems, including the energy consumer**
- **Supports services that improve the energy efficiency of the energy consumption and the energy system (generation, transmission, distribution and especially end-use)**

Such smart metering may be based on an infrastructure for multipurpose metering rather than on several single purpose metering systems. The above definition means that smart metering may support several applications that are defined in chapter 3 of the deliverable D3.

Several other definitions of smart metering, from literature and different authors, are enclosed in the Appendix A of the deliverable D3.

The following applications of smart metering are identified and briefly defined in the deliverable D3:

- Services for monitoring and improving energy efficiency of end use and dispersed generation. Customer information feedback
- End use energy management
- Tariff setting (Time of Use, Maximum Demand, Seasonal)
- Energy saving
- Demand response for electricity market and for network operation support, peak load limitation
- Smart homes, home automation, remote control of appliances by customer
- Connect, disconnect, limit load remotely

- Load analysis, modelling and forecasting (for energy markets, network operation and planning, energy saving, etc.)
- Settlement and billing
- Virtual Power Plant, embedded renewables and cogeneration
- Improving competition and efficiency in energy markets
- Customer service by DSO, RESC and ESCO
- Fraud detection
- Providing information for authorities and researchers
- Meter management
- State estimation of power distribution networks
- Monitoring of power quality and reliability
- Prepayment
- Ancillary services such as frequency controlled reserve, voltage and reactive power control
- Analysis of failures and preventive maintenance
- Safety, security, telemedicine, social alarm services

The above list is ordered according to the importance of smart metering applications according to the combined view of the deliverable D3 authors in the beginning of the ESMA project.

Sharing of costs and benefits of smart metering is a major challenge in the unbundled electricity market. The deliverable briefly considers qualitative benefits for

- each actor of the unbundled electricity market
- energy consumer
- unbundled DSO
- competitive electricity market
- society and environment
- multi fuel and water supply applications and actors.

Benefits and beneficiaries of different applications are discussed and key factors influencing the success of smart metering projects are listed.

There is a need to develop automatic meter reading to serve many more applications than only the traditional basic settlement, billing and load control. The combined view of the authors of this report is that end use energy efficiency improvement & customer feedback, energy management, energy saving and demand response are very important applications of smart metering that merit and require further development.

2. INTRODUCTION

2.1. Background

Developments in technology enable distributing data processing and storage at low costs. Availability of energy is limited. Emissions need to be reduced. The share of dispersed power generation is increasing. Energy markets are being restructured and opened to competition. Response and controllability of dispersed generation and demand need to be increased. Automation has potential to give savings in investments, energy, emissions and labour costs. Improved metering is needed to enable this potential.

European Smart Metering Alliance (ESMA) is an Intelligent Energy Europe project that collects and disseminates information improving energy efficiency via smart metering. Experience, barriers and solutions are covered. The scope is in domestic and small business customers in European countries.

2.2. Objectives of this report

The objectives of this report are the following:

- define what smart metering means in ESMA
- define the applications of smart metering
- identify the potential benefits of smart metering
- describe the state of the art regarding the above points.

The purpose of this report is to define the meaning of the key issues in ESMA. ESMA is in particular focusing in maximising the energy efficiency benefits of smart metering, linked to Article 13 of the directive 2006/32/EC on Energy End-Use Efficiency and Energy Services (ESD) and seeking to build a community of stakeholders in order to support discussions on key topics and to ensure that all relevant views have been accounted.

Making specification and design choices is outside the scope of this report.

2.3. Outline of this report

First definitions for smart meters and smart metering are considered. Then the applications of smart metering are briefly described in Chapter 3. In Chapter 4 the relative importance of the applications is considered in order to provide some basis for the definition of what are the core functions and optional functions. Finally the benefits of smart metering are qualitatively identified and described. The quantitative analysis of the benefits based on reported experience is not in the scope of this report, but it is covered in other tasks in ESMA.

3. DEFINITION OF SMART METERING

3.1. Smart meters

Meters have been called smart since the introduction of static meters that included one or more microprocessors. Already about 15 years ago for big customers there were meters that met the present definitions of smart meter.

Often a meter is called smart to imply that it includes significant data processing and storage for various purposes such as:

- monitoring that the meter is installed correctly and working properly
- data communication with the meter using secure and open standard protocols
- updating the meter software remotely over the communication network
- multi utility metering (electricity, gas, heat and water)
- calculating and monitoring power quality characteristics
- automatic reading of consumption measurements for billing and settlement, and for the analysis of energy end use
- providing real time consumption data to various actors (distributor, retailer, end user) and their automation and energy management systems
- management of tariffs
- load response (load management and control)

Smart meters have been mentioned in the literature already in the early 1990´s, (De Almeida and Wine, 1993) and (Koponen et al., 1996), for instance. In 1993 the solid state meters were still rather new and 10 - 20 times as expensive as the electromechanical meters. Thus their use was mainly limited to large customers. The following capabilities were considered necessary:

- two way communication
- collection of load data for demand side evaluation, tariffing, load forecasting, and planning
- programmable time resolution ranging from one minute to one day
- tariff management (dynamic tariffs, remote meter reading, automatic printing of bills)
- load control
- information to customers
- distribution automation and monitoring the quality of supply.

When the number of remotely readable smart meters increased, it became necessary to develop better systems for meter reading and data management. An example of the state of the art in mid 1990's is given in (Saari et al., 1996). With such systems the metered data started to become available to other systems, but most these other systems were not yet ready to use such data. These other systems include systems for distribution network automation and management, and customer information. Similarly, timely consumption data from billing meters was seldom used to end use energy management and energy automation or for regular assessment of the potential for energy savings.

Static meters are replacing electromechanical meters. Distributed data processing and storage capacity have become very cheap in mass produced meters and these factors do not any more limit the possibilities to add smartness to small customer meters.

3.2. Smart metering

There is no universally agreed definition for smart metering. Thus, in order to have a common understanding, it is necessary within ESMA to give a definition. This definition should cover all the applications in ESMA and therefore should not be application dependent. Figure 1 illustrates the context and some applications for smart metering.

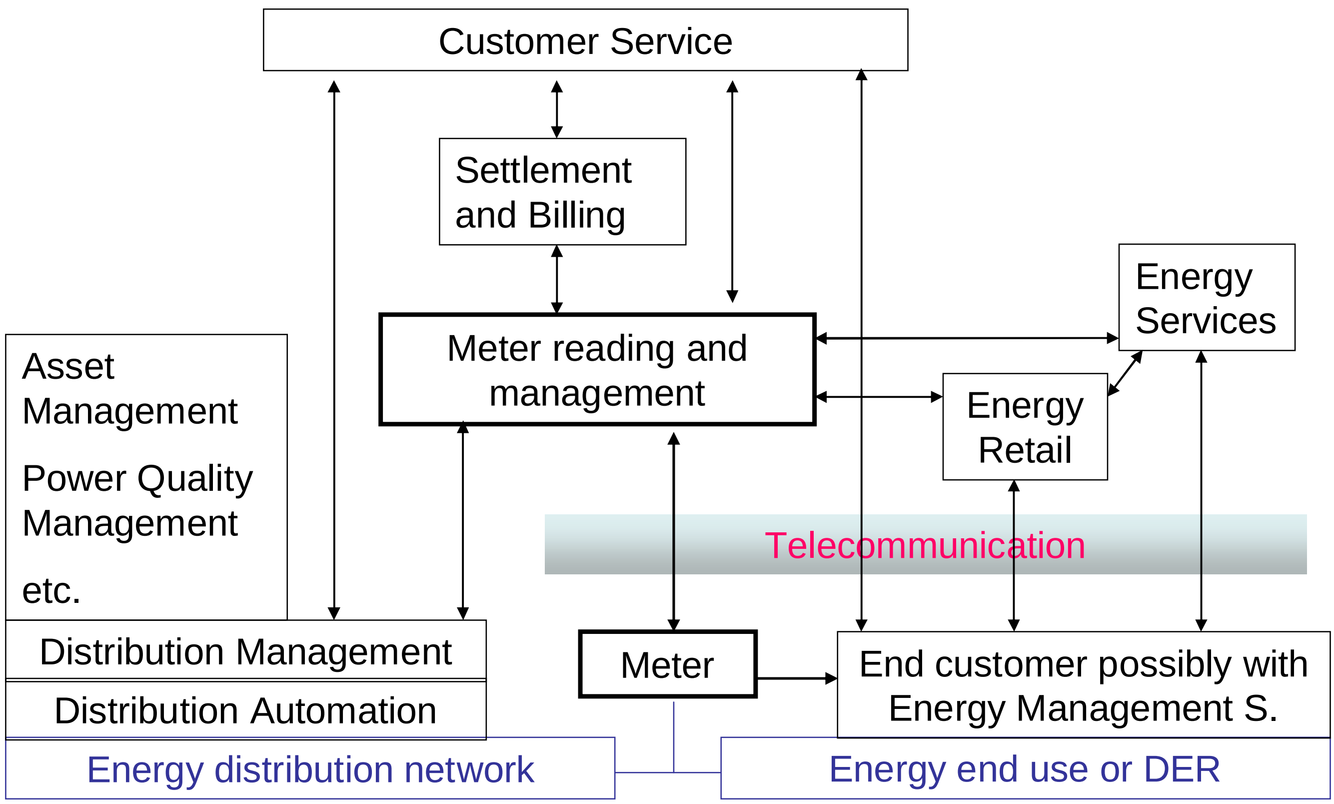

Figure 1. Many applications and users can benefit from a smart metering infrastructure

There are increasing needs and possibilities to combine data stored in Metered Value Data Bases and meters with data stored in other existing databases that include customer information, geographical information, information on distribution network structure, state, operation and power quality, information on end use and building properties, authority requirements, etc. Such combination usually requires development of the systems.

Typically smart metering means that the business processes and technical systems related to metering are smart and highly automated. Manual work may be slow, costly or unreliable, when large masses of metered data are collected and processed. Usually smart meters are used to achieve a highly automated process called smart metering, because distributing data processing and storage to meters is a cost efficient way to improve the functionality, reliability and robustness of metering.

In ESMA the definition for smart metering is set as follows:

Smart metering has the following features:

- **Automatic processing, transfer, management and utilisation of metering data**
- **Automatic management of meters**
- **2-way data communication with meters**
- **Provides meaningful and timely consumption information to the relevant actors and their systems, including the energy consumer**
- **Supports services that improve the energy efficiency of the energy consumption and the energy system (generation, transmission, distribution and especially end-use)**

Attributes for 2-way communication, such as reliable, secure, open, standard, etc., cannot be included in the ESMA definition, because complete set of such requirements would more or less exclude most of the existing smart metering systems and installations from the scope.

Such smart metering may be based on an infrastructure for multipurpose metering rather than on several single purpose metering systems. The above definition means that smart metering may support several applications that are defined in chapter 3.

Often "advanced metering" and "advanced metering infrastructure (AMI)" are used more or less as synonyms to the above definition of smart metering. United States Federal Regulatory Commission (FERC) gives the following definition: *Advanced metering is a 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 central collection point.*

Several other definitions of smart metering, from literature and different authors, are enclosed in the Appendix A, including the definition of (Energywatch, 2005).

4. APPLICATIONS OF SMART METERING

4.1. Settlement and billing

More accurate settlement

Smart metering improves settlement procedures by providing accurate and rather up to date consumption data for metering points. Thus most needs to estimate consumption data and correct the settlement and billing afterwards are removed. In other words DSOs may eliminate costly additional settlements procedures.

More frequent and cheaper switching of retail electricity suppliers

One of the core functions in Smart Metering is a possibility to request metered data from a metering point at any time. Considering that regulators require steady shorter periods for changing of retail electricity suppliers (in Norway it is two weeks now and will be reduced even further) possibility to read data remotely at any moment of time, reduces costs for DSOs. In the future it will also provide a possibility to implement an automated supplier-switching procedure.

Correct and timely billing

The EU Commission emphasises in its ESD Directive 2006/32/EC the importance of providing actual energy consumption data to customers and billing, based on actual consumption data. Smart Metering obviously enhances this possibility.

4.2. State estimation of power distribution networks

Today the knowledge of the power flows at and near the low voltage end of the distribution networks is often very inaccurate, because it is typically based on network models, estimated loads and measurements at primary substations. By adding measurements taken at, or near, the customer point of connection (kWh-meter) the loading and losses of the network can be known more accurately. This can help to prevent overloading components (transformers and lines) and to avoid power quality deviations.

State estimation is an advanced technique, where a large number of measurements from a network are combined with a model of the physical network and its loads. The combination of measurements and model allows calculating both unknown variables (e.g. losses or reactive power flow) and to identify unreliable measurements and other dubious model input data. A sample of all meters can be used to measure the demand in very small time intervals (e.g. 1 or 5 minutes) and used for state estimation.

4.3. Monitoring of power quality and reliability

Power quality covers the voltage quality supplied by the distribution network and the current quality of the loads. Adequate voltage quality in AC-networks means that the voltage does not deviate too much from the ideal voltage. An ideal alternating voltage is a perfect sinusoid with the rated constant amplitude and frequency. In multiphase systems it must also have certain phase order and symmetry with respect to the phases. A more specific voltage quality description is the European Standard EN 50160. Most voltage quality problems originate from customers, but the distribution company is responsible for the voltage quality at the point of customer connection. The kWh-meter is in this point.

Continuous monitoring of voltage quality enables fast and accurate response to customer complaints. It also enables preventive reaction to power quality problems, before any harm or damage to the network or to the customers occurs. The traditional approach of bringing power quality analyser to the complaint location after a complaint is inefficient and labour intensive and is inadequate as a proof of power quality during the incident causing the complaint.

Recording of the power supply interruptions, voltage dips and some voltage quality characteristics as experienced by the customers helps distribution companies to understand where network investments are most needed and what kind of power quality related advice to the customers is relevant. Roughly the same voltage is received by many customers; thus detailed monitoring of the voltage quality at every kWh-meter is not needed. Integrating power quality monitoring to smart metering of consumption can give advantages such as sharing dispersed equipment, installation, maintenance and communication networks.

4.4. Customer service by DSO, RESC and ESCO

Customer service includes providing customers with relevant information on

- energy network faults, maintenance, repair and installation
- customer connection and disconnection
- power quality
- their energy consumption and energy efficiency and energy saving possibilities
- possibilities to save in energy costs

Smart metering can improve the efficiency and service quality of the customer service call centres. Up to date measurement based information available to the control centre enables fast and accurate service and partial automation of replies.

Customer service includes also connection and disconnection of loads, giving mutually beneficial offers that enable customers to reduce their energy costs or improve their energy efficiency.

Fast, accurate and predictable service improves customer satisfaction.

4.5. Load analysis, modelling and forecasting

Consumption data for gas, electricity, heat and water can be used for load analysis. E.g. hourly data combined with information about type of consumer can be used to construct user profiles, e.g. a standardized profile for single family houses with electric heating or supermarkets or an industrial sector. Such profiles can be based on a statistical sample and can be representative for the type of end user type. The dependence of the load on the type of the day as well as on outdoor temperature and possibly other environmental variables can be modelled. By combining simple information with the load profiles, time variations, total energy use and peak demand can be estimated and forecasted.

Such information is useful for retail suppliers and their customers. It is also useful for the DSO when planning or operating the power distribution network. Detailed energy use information can also be used to evaluate energy savings campaigns. This can be done by combining information about the end use activity with the development of energy consumption. Potential targets for energy efficiency improvements can be identified by comparing properties of the building (taken from databases and building requirements) with the measured consumption.

4.6. Improving competition and efficiency in energy markets

Smart metering improves competition on the energy market in following ways:

- Providing correct metered data allows to shorten or possibly to automate retail energy supplier switching procedures.
- It also makes it easier for retail electricity suppliers to gain metered data for potential customers and make better electricity contract offers to them.
- Smart Metering diminishes technical barriers between national markets and makes it possible to create international electricity retail markets. For example the establishment of the Nordic Electricity retail market has been pointed out as an important objective for Nordic Council of Ministers.
- Smart metering may enable new electricity market products that improve the interaction of the small electricity consumers with the electricity market. This results in more energy efficient operation of power generation resources.
- New products that improve demand response bring more price elasticity to the electricity market thus reducing the risk for electricity market failures and collusive market behaviour.

4.7. Demand response for electricity market and for network operation support, peak load limitation

Demand response means controlling loads and embedded generation as a response to electricity prices. Demand response covers price control and direct load control. Price control means that the customer is subject to time variable prices, such as prices following fast variations in the spot-market prices. Direct control means that some aggregator (retailer, virtual power plant operator or distribution company) sends signals that switch loads off and on depending on the situation in the market and in the electricity network.

There are three broad types of tariffs for price control: time of use tariffs, real time tariffs and critical peak tariffs as explained in more detail in (CER 2007). Time of use tariffs reflect regular repeating seasonal and daily variations in production costs or bulk electricity market prices. Real time tariffs reflect the real fast price variations in the electricity market. In critical peak tariffs time of use tariff is applied most of the time and a high peak price during days, when there is a shortage of production capacity, marginal production costs are high and it is thus important to reduce the demand. Combinations of these categories are also possible.

Price control can be used to reflect the electricity prices on the competitive bulk market or the time variable distribution network tariffs, or ideally the sum of these two components. Time variable distribution tariffs originate from a regulated natural monopoly and are used to level the loading of the distribution network. Competitive electricity markets provide rather neutral reference prices such as the spot-market price. These are useful for price control.

Storing electricity is expensive and causes losses. Thus it is necessary to maintain the balance of generation and consumption in the power system at any instance. Adequate price elasticity is necessary for the proper operation of the electricity market. The possibilities to fast control of big nuclear power plants, fossil bulk generation plants and big CHP-plants is limited and expensive. Increasing penetration of wind and solar power also increase the need for controllable resources. Fast controllable generation and peak power generation are often expensive compared to the energy they produce and have low efficiency. Thus the importance of controlling both demand and distributed generation is increasing. Fixed time of use tariffs may be too rigid to adapt to the foreseeable developments in the electricity market and infrastructure, and lead to stranded investments. Real time tariffs and critical path tariffs are more future proof. Smart metering can enable demand response.

Demand response and smart metering are discussed in (CER 2007). More information on demand response is on the website www.demandresponseresources.com of IEA DRR (International Energy Agency, Demand Response Resources).

4.8. Ancillary services such as frequency controlled reserve, voltage and reactive power control

Ancillary services are all services necessary for the operation of an electricity transmission or distribution system; see Electricity Directive (2003/54/EC). These include compensation for energy losses, frequency control, balancing, voltage and power flow control and restoration of supply.

Smart meters may include remote control functions with local control outputs and local measurements of frequency, reactive power and voltage level. These enable to some extent the provision of ancillary services with distributed energy resources.

4.9. Services for monitoring and improving energy efficiency of end use and dispersed generation, Customer information feedback

The information obtained from the utility meter, in particular about energy consumption, shall be provided to the end user; in this way the end user would be in the position to both reduce its energy consumption or to shift its energy use.

For end users with interconnected distributed generators, the meter measures both import and export. The display should enable the end user to maximise their benefit from the embedded generator, for instance by indicating to them when they have surplus generation that can beneficially be used in house, rather than exported.

Concerning interconnected distributed generators, it is important to note that:

1) The data should originate from the utility meter to avoid issues over reconciling data from multiple sources. This data may be taken from the metered value data base and presented to the customer over the internet. For the customer it is better to get the data directly from the meter, because delays make fast responses impossible and because there is a small risk that some data base data is estimated and not measured due to system failures.
2) There is no agreed best practice on how the information should be provided to the end user, such as graphs, numerical data, kWh's, CO_2 emissions or financial basis. However, it is assumed that the information is updated frequently, such that the end user can recognise their usage patterns. The ESMA project does not favour any method at present.
3) A number of different routes are possible for providing information to end users, such as displays linked to the meter or web pages accessible over the Internet. The ESMA project does not favour any route at present.
4) Supplementary information should be provided to the end user, such as a guideline on how to make energy savings using metering data. This information should be designed to complement and integrate the data provided by the information display.
5) End users may not be willing to reduce their consumption although their energy supply contracts may reward them financially for shifting or reducing consumption.

4.10. Providing information for authorities and researchers

Different authorities and researchers need measurement data in order to know the situation and the potential to improve it. Such information is needed both on the loads and on the electricity distribution and energy retail market. Some authorities and researchers are interested in analysing energy end use and some (such as regulating authorities) the quality of the network, its voltages and the services provided by the power distribution companies. Fast and accurate feedback on the energy efficiency measures allows choosing and tuning most efficient ways to improve energy efficiency and regulation of the natural network monopolies.

4.11. End use energy management

Growing world economies, increasing energy demand, actual global climate change issues, political and economical interests' interactions in energy markets make governments, European Union, researches, specialists and other people more aware of energy consumption and its efficiency. In the past 25 years worldwide energy consumption had risen by 30% and total energy consumption is continuing to increase significantly despite energy efficiency initiatives taken in different parts of the world (Lopes et al, 2005). Finding most appropriate ways of improving energy efficiency and saving energy requires a clear picture of energy consumption patterns and trends.

End use energy management means minimising energy costs while meeting the energy end use requirements such as keeping indoor conditions (temperatures, air quality, lighting) or other processes within a certain range that may vary with the usage of the building. This is roughly equal to improving energy efficiency of the consumption and its whole energy supply chains. Small residential customers still very seldom have an energy management system. Some smart homes have automation systems that include some energy management functions. Medium commercial customers use widely facility management systems that include energy management functions. End use energy management system needs real time (1 - 5 minute) consumption measurements preferably directly from the billing meters.

With traditional electro-mechanical energy meters, it is hard to determine the efficacy of different energy efficiency initiatives and how do they influence consumers' behaviour. Small customer end use energy management is just in its infancy, because it mainly depends on consumers' understanding and awareness on energy consumption, on the availability of information about energy efficiency, and on energy automation.

Mostly energy meters are placed far away from consumers' everyday view (Wood, 2006). Thus consumers have quite vague idea about how much they consume energy in total, for different processes and how they can influence their energy consumption by changing day-to-day behaviour or implementing energy efficiency measures (Darby, 2006).

4.12. Energy Saving

Smart Metering contributes to energy savings in several ways:

Direct use of timely and correctly metered data by final customers

Smart Metering provides continuous information about actual electricity consumption giving customers better control of their use of energy by:

- Following and adjusting their consumption patterns
- Identification of abnormal consumption of energy due to, for example, malfunctioning equipment, open windows, or poor house's insulation and further improving of the situation.

Metered data provides a technological basis for new products and services

Smart Metering provides technologic basis for retail electricity suppliers, DSOs and possibly other market actors to offer Final customers new products and services, which will encourage energy saving. These new products can be based on meter's core functions – providing timely and accurate metered data as for example: different types Time of Use network tariffs, spot-price electricity contracts or electricity contracts with buy-back options. Some products may require optional functions as, for example, remote load control, providing additional information about prices or/and tariffs, costs etc.

4.13. Smart homes

Smart homes are homes where different appliances, machines and other energy consumers are connected in one network, which is controlled according to inhabitants' needs and behaviours, outdoor climate and other parameters. Home automation and remote control of appliances by customer become more and more frequent, as in homes appear new technology appliances, heating systems and alarm systems. These can be interconnected with lightning, ventilation systems etc. and can work jointly. A unified system would allow more efficient control of energy consumption. But at the same time even in smartest homes consumer's behaviour is the uppermost factor in energy consumption, because consumers determine the factors according to which the control system works. With too complex systems consumers lose interest in monitoring their energy consumptions and taking energy saving measures (Wood, 2006).

Smart metering (within the scope of the ESMA project) is primarily concerned with the provision of additional information to end users so as to change their energy usage behaviour. Going beyond this simple interpretation of smart metering it is feasible to make a number of links to other control and information systems within the house. These links can increase the information available to the end user and/or improve their understanding of the information. Additionally, it may be possible to use the meter data to automate energy saving and demand response measures. Home automation also offers the ability to let the end user control individual appliances in response to information obtained from the meter data. Finally, where a local infrastructure has been installed to support home automation, this can be used by the smart metering system in place of its own.

Examples:

1. Combinations of data streams

A central heating control system could provide an additional data stream that can be combined with the meter data (gas and electric) to provide a more meaningful view of the energy usage in the house. Also, individual appliances could report their usage so that the meter data could be de-composed to show a more meaningful picture of the house energy usage patterns.

2. Energy Automation

Demand response depends on shifting energy demand periods. This can be done manually but this reduces its effectiveness as end users may be unavailable to respond or disinclined to do so. Linkage between the smart meter and home appliances could allow the appliances to be controlled via the meter communication link according to the energy supply contract with the end user. Other energy savings measures, such as turning of lights or standby appliances according to a time programme could also be offered. In the future home energy management may include dynamic models and optimisation of energy use taking into account occupancy, environmental conditions, time variable energy price and preferences of the inhabitants.

3. Smart Homes Infrastructure

A number of home automation schemes involve the installation of local communications networks to allow individual appliances to communicate and control each other. For example, the PLC protocol ‘Home Plug’ has been developed to allow smart devices to communicate across the house mains wiring. Other wireless schemes are being developed with a view towards home automation, such as Z-Wave and Zig-Bee. If these communications networks become common then the smart meter could utilise the network to avoid the cost of installing one of its own and to enable ready communications between the meter, the household appliances, temperature and other measurements and any software applications running the smart systems.

4.14. Virtual Power Plant, embedded renewables and cogeneration

“Virtual power plant” describes a control structure where a large number of small generation units and other small energy resources (such as controllable loads) are controlled to act as a big power plant. Virtual power plant is a useful concept because remote monitoring and operation as well as aggregated energy market connection are needed for small energy resources. Small generation units are often needed for generation from local renewable energy sources and cogeneration of heat and electricity, because long distance transfer of heat or bio-fuels is not feasible. Also many hydro, wind and solar power generation sites and controllable loads are small.

Many small generation units and loads can be controlled much faster than most big power plants provided that communication is reliable and fast enough. As the penetration of distributed generation and generation from renewable energy sources increases, it becomes necessary to use smaller units than before as controllable resources for the electricity market and for ancillary services of the electricity networks.

The smart meter can measure the generation from each unit (or the balance between local demand and generation). The control of the local generation could typically happen independent of the meter, e.g. by the Internet or by mobile phone technology, but it is also possible that the smart meter is used for the communication.

4.15. Preventive maintenance and analysis of failures

Measurements may help preventive maintenance of distribution grid components and meters as well as customer equipment. For example, faulty power electronics, loose cables or grounding or broken bearings may cause rising levels of certain power quality characteristics such as distortion, certain harmonics, DC-component or voltage asymmetry.

Measurement data from the grid and its customer connection helps analysis of the development and reasons of component failures and grid outages.

4.16. Safety, security, telemedicine, social alarm services

Smart metering provides a secure communications channel between the end user and their energy supplier or other agent plus, optionally, an in-house communications network. This infrastructure can be used to provide additional services. These include:

1. Safety

Fire, carbon monoxide and other safety related alarm signals can be transmitted via the smart metering communications channel. The infrastructure must deal with directing the information to the correct recipient and validating the alarm, if appropriate.

2. Security

Burglar alarms and panic alarms signals can be transmitted via the smart metering communications channel. The infrastructure must deal with directing the information to the correct recipient and validating the alarm, if appropriate.

3. Telemedicine

Smart metering infrastructure can be used to transmit medical data from patients to medical experts. This would depend on the security and reliability aspects of smart metering systems.

4. Social Alarms

Smart metering may support monitoring services for of the homes of the aged. Alarming temperatures and usage patterns of electricity and water may be detected, for example.

These services most likely are going to be somehow regulated. EU and national regulators are concerned about cross-subsidising of these services. Competition in these services may be severely distorted if natural distribution monopolies participate in it.

4.17. Prepayment

A meter with integrated contactor linked with a process to collect money from the consumer in advance. Power is only provided whilst the consumer is in credit. Smart meters may enable more cost efficient, flexible and customer friendly prepayment than traditional prepayment meters.

4.18. Meter management

Meter management comprises the following activities:

- management of installed metering asset

- maintaining a meter database of vendor, type, age, tariff and configuration settings, working life, record of safety and security checks
- scheduling visits where necessary or obligatory
- ensuring that the meters are correctly installed and operate correctly by detection of meter faults and installation errors etc. Smart meters may include functionality to detect meter faults and installation errors. State and load estimation with redundant meters and models helps to detect suspicious meters and models.
- checking that the meter location and customer are correct stored in the meter database

4.19. Connect, disconnect, limit load remotely

These functions are normally optional for Smart Metering. These functions are very important for the DSO to control the load, however. They are also used to decrease fraud. Implementation of these functions may result in a considerable increase of capital and operational costs. It may also require use of more complicated protocols for transfer of data, which may create interoperability problems.

Remote connection and disconnection of the total load (the whole metering point)

This function is often applied by DSOs for metering points, with a frequent change of Final Customers. It can be also used by DSO as a part of power rationing schemes. In some countries this function is important. However, wider application of this function in several countries is limited by safety rules, prohibiting remote re-connection of customers' loads and so-called delivery obligation ensuring that all final customers receive electricity for their basic needs. The last one also hinders DSOs to use this function against so-called non-revenue customers.

Remote connection and disconnection of partial loads

Control of partial load by remote disconnection of predefined circuits can be used by DSOs as a part of power rationing schemes or/and DRR-related schemes in general. Customers can, for example, assign specific loads to remotely controlled circuits in their houses, which can be remotely disconnected if spot-price exceeds a certain predefined value.

Remote limitation of max allowed capacity for a metering point

This function reduces the max allowed capacity for a metering point, without disconnection of the whole metering point. This function is more flexible, compared to disconnection of the total loads and complies better with safety requirements and delivery obligation. This function can be applied for collection of payments from non-revenue customers or in power rationing schemes. In some cases DSO are willing to buy back max allowed capacity for certain metering points in order to reduce congestions on local distribution network.

4.20. Fraud detection

Here fraud means illegal withdrawal of energy from the grid or affecting billing by tampering the metering system, etc.

Electromechanical meters have a number of features designed to reduce fraud. For instance, the meter may feature a stop to prevent it from running in reverse. Smart metering must, at least, provide an equal degree of revenue protection. This is made more complex because, a major benefit of AMR is the removal of the need to physically visit meters. This means that the meters will not be inspected, implying that the meter itself should provide information on any fraud attempts. Also, to some extent, smart metering may introduce immature new features that create new opportunities for fraud, but more importantly smart metering can enable timely detection of various fraud attempts.

Smart meters are able to detect and to promptly signal any illegal attempt to:

- open the meter box,
- modify the connections to the meter
- re-program the meter software.

In districts where there is a high risk of fraud, together with smart meters could be installed units for measuring the energy balance of the system. Then in case the difference between the transformed energy and the sum of the energy measured from the connected customers is significantly below the technical energy losses, the utility could start an investigation to detect possible fraud.

Meter manufactures believe that it is possible to deliver greater levels of revenue protection with smart meters than with electromechanical meters. Indeed, revenue protection is itself a justification for switching to smart metering where levels of fraud are high. Defining revenue protection features is difficult, because there has been no agreement on standardising them and manufacturers believe that they can offer differentiated revenue protection features.

A basic definition would be:

The smart metering system shall offer revenue protection features such that protect against end users defrauding the utility providing them with their energy services.

Notes:

1) Revenue protection features should take account of developments in distributed generation; power export can no longer be assumed to be a sign of fraud.
2) Meters should automatically report any attempt at fraud, as it cannot be expected that they are physically inspected.
3) The smart metering system provides at least the equivalent level of fraud protection as conventional or existing meter systems.
4) The smart metering system shall ensure that communications are secure and reliable.

4.21. Tariff Setting (Time of Use, Maximum Demand, Seasonal)

The setting of switching times and seasons for time of use registers, maximum demand registers and setup of any other register against which a tariff is applied for the purpose of billing.

5. IMPORTANCE OF APPLICATIONS IN ESMA

In ESMA the main focus is on energy efficiency and on small customers. The smart meter provides support for improving energy efficiency. Thus it should support at least one of the following functions:

- improve customer awareness of energy use
- provide timely consumption data to smart home system and its energy management
- enable retail supplier to control the load and dispersed generation either directly or via price signals that reflect electricity market price variations.

The main purpose of smart metering traditionally is to provide meter values needed for billing and settlement and increasingly also to some extent for energy distribution network automation. Often even more important are the load management functions implemented via the automatic metering systems. The smart metering may also include control functions for supporting billing.

In the beginning of the ESMA-project the importance of the applications for ESMA was estimated by the partners of this task as shown in the following table 1.

Table 1. Importance of smart metering applications in ESMA, combined view of the ESMA WP2 T4 partners at the beginning of the project (Average and maximum of individual ratings per partner are shown)

Applications of smart metering / Importance in ESMA >>	Average	Max
Services for monitoring and improving energy efficiency of end use and dispersed generation, Customer information feedback	4.40	5
End use energy management	4.40	5
Tariff Setting (Time of Use, Maximum Demand, Seasonal)	4.29	5
Energy Saving	4.00	5
Demand response for electricity market and for network operation support, peak load limitation	3.70	5
Smart homes, home automation, remote control of appliances by customer	3.60	5
Connect, disconnect, limit load remotely	3.50	5
Load analysis, modelling and forecasting (for energy markets, network operation and planning, energy saving etc.)	3.50	4
Settlement and billing	3.30	5
Virtual Power Plant, embedded renewables and cogeneration	3.30	5
Improving competition and efficiency in energy markets	3.30	5
Customer service by DSO, RESC and ESCO	3.30	4
Fraud detection	3.10	5
Providing information for authorities and researchers	3.10	4
Meter management	2.67	4
State estimation of power distribution networks	2.50	4
Monitoring of power quality and reliability	2.50	4
Prepayment	2.40	5
Ancillary services such as frequency controlled reserve, voltage and reactive power control	2.40	4
Analysis of failures	2.40	4
Preventive maintenance	2.20	3
Safety, security, telemedicine, social alarm services	1.70	4

The table gives some basis for defining, what are the core functions and optional functions of a smart metering system, but other input information is also necessary. For example, the stability of the requirements should also be considered: the core functions should preferably be such that they do not have any significant changes in the future, while the optional functions could still be under development both in terms of technology and regulatory requirements.

For certain applications the rankings by the experts differ quite much. Likely reasons for this include the following:

1) The situation varies from country to country; for example, applications enabling controllable and predictable loads and dispersed generation are less important in countries that have excess controllable hydropower.
2) Experts are specialised to different applications and see the relative importance accordingly.
3) Different mutual weighting of smart metering in general against energy saving objectives of ESMA.

6. BENEFITS OF SMART METERING

6.1. Benefits for each actor

Sharing of costs and benefits of metering is a major challenge in the unbundled electricity market. The actors or the roles comprise the following:

Small consumers	
Large consumers	
MO	Meter Operator
DSO	Distribution System Operator
SO	System Operator
RESC	Retail Energy Supply Company (= electricity retailer)
ESCO	Energy Service Company
GENCO	Generating Company (Both generation and distributed generation)
Authorities	
R&D organisations	

In many market setups the Distribution System Operator (DSO) is responsible for consumption metering. Even in that case many DSOs outsource metering to a separate meter operator (MO). In some market setups it is compulsory that metering is unbundled from distribution. Typically over 80% of the potential benefits go to other stakeholders than DSO. Realisation of these benefits requires some additional investments. There are synergies with metering and other remote monitoring, control, communication, installation, maintenance, assistance and advice services. Thus such a service provider may also be a meter operator.

Distribution networks and consumption metering are also needed for water supply and for other energy forms, such as gas and heat. The actors of these infrastructures also benefit from smart metering.

At the moment most of the functionality of the existing new AMR systems is not used, because various systems and some market rules need to be developed first. Often the reason for not using them is not the lack of need but the lack of systems that can filter the information into a useful form and integrate it into the existing systems. Development and integration of new applications is also discouraged by the fact that advanced functions in AMR systems are often implemented with proprietary extensions of open standard protocols or with fully proprietary protocols.

6.2. Benefits for energy consumer

The benefits of smart metering to the other actors generally benefit the consumer by reducing costs of energy and its distribution. Competition and regulation help to transfer this kind of benefits to the energy consumer. In addition, smart metering may bring consumer direct benefits such as

- more accurate and timely billing
- improved access to the electricity market via accurate consumption history and possibilities to benefit from demand flexibility
- feedback on energy consumption to the consumer and his energy automation systems
- improved safety of humans and equipment through better power quality and fault management

Customers pay eventually everything, but their interests are only marginally taken into account. The unbundled electricity market is fractionalised. Regulated monopoly actors as well as oligopoly actors of the competitive market may lack incentives to serve customer interests. Also competition may force actors to local optimisation. Local optimisation by each unbundled actor alone does not lead to a globally optimal metering infrastructure. Relatively short lifetime of the meters and metering systems as well as poor compatibility between systems from different manufacturers or system generations reduces the potential to gradually develop systems and thus limits benefits and increases costs.

Metering affects the energy efficiency and cost efficiency of the whole energy system including generation, distribution and loads. Improved and timely access to metering results may enable customers to make substantial energy and cost savings.

6.3. Benefits for an unbundled DSO

Payback time of AMR investments is too long, if the only objective is replacing manual meter reading and self meter reading. Frequently changing customer at difficult to reach metering points cause relatively high costs for manual meter reading, but installing AMR only to certain areas reduces other benefits and increases cost per meter point. With some additional ICT investments AMR enables simple, efficient and homogenous business processes related to metering, settlement, customer service, state estimation, management of faults and power quality.

In power distribution networks monitoring power quality, power flows and faults in low voltage networks as well as load control give benefits. Problems can be detected and corrected faster. Damage of customers' equipment and risks of compromising human safety can be avoided. Efficiency of outage management and customer service is improved. Temporary overloads that sometimes destroy low voltage transformers can be avoided. Providing consumption data to network information systems etc. and using it there still needs much development. In Italy the AMR benefits to network business are considered biggest at the old urban areas where the loads are rapidly increasing but strengthening the network is difficult. In Finland DSOs expect more network management and operation related benefits from rural networks (long distances makes network strengthening expensive, periods of simultaneous high loads exist, overhead lines, rarely visited consumption points) than from urban networks.

6.4. Benefits for the competitive electricity market

Profile metering enables new retail market products that enable using the controllability of the distributed energy resources at the electricity market. This increases fast price flexibility of the market thus improving competition and better and more reliable functioning of the electricity market. Market risks of retail electricity suppliers are reduced due to ability to react to price peaks and due to reduction of very high price peaks. In some countries market rules and legislation limit the possibilities to use the controllability of small customers in the electricity market.

Some modern meter data management systems are capable of supporting hourly metering based electricity market access of at least hundreds of thousands of customers. They can calculate balances for many retailers etc.

Data mining combining smart metering results with the contents of other data bases (such as customer data bases and data bases on building properties) enables retail energy suppliers to better understand their customers. Products can be designed and targeted more individually. Predictability of loads is improved which reduces costs and risks of the retail supplier. Detailed information on customer behaviour can be a threat on confidentiality and privacy. Thus rules for data mining need to be set in dialogue with consumer bodies.

6.5. Benefits to the society and environment

Smart metering has potential to improve energy efficiency both in the energy supply infrastructure and in the end use. Timely and accurate feedback on energy and water consumption enables consumers, home automation and authorities to react fast enough and to target their efforts to most efficient measures. The effect of different customer feedback mechanisms on energy consumption is discussed in (Darby 2006).

Direct energy saving is not the only benefit type. Connecting small controllable energy resources to the electricity market and ancillary services for the grid enables the use of renewable energy sources and high efficiency CHP-generation in stead of high emission low efficiency peak power plants.

6.6. Benefits to multi fuel and water supply applications and actors

There are distribution networks also for water and some other energy forms than electricity. All of them need consumption metering. Smart metering brings benefits for all of them. Often communication with these other meters is done via a smart electricity meter. This has the advantage that the electricity meter can provide the power supply for the communication. Sharing the remote communication channel can also greatly reduce the combined costs of communication.

Metering of all energy forms is needed to get a complete view of the energy consumption and close the energy balance of the target with metering. Thus for analysing and improving energy efficiency it is often necessary to bring together the measurement results for all the energy forms.

6.7. Benefits and beneficiaries of different applications.

In table 2 the benefit of smart metering to the different beneficiaries are summarised in a qualitative way.

Table 2. Benefits and beneficiaries

Applications of smart metering / Who gets what benefits	Consumer	MO	DSO	SO	RESC	ESCO	GENCO	Authorities	R&D
Settlement and billing	1				3	3			
State estimation of power distribution networks			1						1
Monitoring of power quality and reliability	2		1		1			1	1
Customer service by DSO, RESC and ESCO	1		1		1	1			
Load analysis, modelling and forecasting (for energy markets, network operation and planning, energy saving etc.)	1		1		3	3		1	2
Demand response for electricity market and for network operation support, peak load limitation	1		2	2	2	2	2	1	2
Ancillary services such as frequency controlled reserve, voltage and reactive power control	1		2	2					
Services for monitoring and improving energy efficiency of end use and dispersed generation, Customer information feedback	2				1	2	1	2	
Providing information for authorities and researchers	1		2	1	2	2	1	2	2
End use energy management	3				2	3		2	1
Energy Saving	3				2	2		2	1
Smart homes, home automation, remote control of appliances by customer	3				2	3		1	1
Virtual Power Plant, embedded renewables and cogeneration	2				2	2	2		1
Preventive maintenance	1	1	1			1			1
Analysis of failures	1	1	1		1	1		1	1
Safety, security, telemedicine, social alarm services	2	1						2	1
Prepayment	1				2				
Meter management	1	3	1		1				
Connect, disconnect, limit load remotely	1		2		2	2			
Fraud detection	1				3	2		1	
Improving competition and efficiency in energy markets	3		1		2	3		3	1

Legend: 1= some benefit, 2 = significant benefit, 3 = much benefit, 4 = very much benefit

The identified types of benefits of smart metering are the following:

- Improves accuracy trough timely feedback and automatic detection of errors
- Replaces manual work with automation
- Saves costs
- Enables energy savings
- Enables faster service based on real time data
- Improves flexibility
- Enables new or significantly improved services
- Improves asset management and maintenance
- Replaces outdated systems
- Enables improved reliability (fewer errors and missing or estimated data)
- Simplifies business processes
-

In our preliminary analysis on which types of benefits go to which actor and application, many benefit types were in most of the cells. Thus a more detailed identification and analysis of the benefit types is left to the later tasks in ESMA.

Benefits of additional smart metering functionalities have been assessed, for example, in a cost benefit analysis in Australia by NERA Economic Consulting, (NERA 2007). The base case scenario comprises the assumed core functionalities listed in Appendix A definition 14). The benefits have been quantified to each additional functionality. The identified key drivers of the benefits were: 1. changes in demand; 2. operational efficiencies; 3; improvements in service quality. It was found that the benefits outweigh the costs for 11 additional functionalities while 5 more functionalities require further analysis and for 6 functionalities the benefits are not expected to out weight the costs. The analysis is intended to assist in defining minimum national functionality for a roll out of smart meters.

6.8. Key factors influencing the success

The payback time of smart metering projects may be influenced by several factors such as:

- Electricity price and how much it varies
- Controllability and predictability of power balance in the system, balancing costs
- Electricity market set up, market rules and regulation
- Size of market area with common specifications and size of the project, standardisation
- To all or to selected customer groups
- Integration to other ICT systems, the quality of these other systems
- Reliability of the metering systems
- Costs of installation, commissioning and maintenance, number of site visits
- Cost of manual work that is automated
- Communication costs, especially if provided by a 3rd party (for example operator of GSM/GPRS network)
- Lifetime of the meter and the supporting infrastructure, especially communication

- Future compatibility with new system generations and with other vendors. It is likely that advanced meter functionalities are implemented using proprietary protocol features that may prevent future development of new services based on these functionalities.
- Business models, level of outsourcing, organisation of work, utilisation of synergies

7. SUMMARY AND CONCLUSIONS

Because there is no universal definition of smart metering, for the context of ESMA a definition was developed. This definition is as follows:

Smart metering has the following features:

- **Automatic processing, transfer, management and utilisation of metering data.**
- **Automatic management of meters**
- **2-way data communication with meters**
- **Provides meaningful and timely consumption information to the relevant actors and their systems, including the energy consumer**
- **Supports services that improve the energy efficiency of the energy consumption and the energy system (generation, transmission, distribution and especially end-use)**

Replacing meters is much more expensive than future proof meters. Thus identification of potential applications and benefits for each stakeholder and specification of common metering requirements that cover those needs are needed.

There are needs to develop automatic meter reading to serve many more applications than only the traditional basic settlement, billing and load control.

The combined view of the authors of this report is that end use energy efficiency improvement & customer feedback, energy management, energy saving and demand response are very important applications of smart metering. Integration of metering with new applications has potential to bring benefits such as reductions in costs and improvements in functionality, service quality, flexibility, energy market access, and energy efficiency. In many cases such integration still requires solving or circumventing technical, regulatory and business barriers.

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Appendix A.

Definitions of Smart Meter and Smart Metering

1) In Wikipedia, the free dictionary, there is the following definition for a smart meter:

" A Smart meter generally refers to a type of advanced meter (usually an electrical meter) that identifies consumption in more detail than a conventional meter, and optionally communicates that information via some network back to the local utility for monitoring and billing purposes.

Similar meters usually referred to as time-of-use or interval meters have existed for years but Smart Meters usually involve a different technology mix such as real-time or near real-time reads, power outage notification, and power quality monitoring."

2) Energy Watch (www.energywatch.org.uk) report "Get Smart, Bringing meters into 21st century" published August 2005:

" Although there is no universal definition of a `smart´ meter the following functions are available:

- Display and record real time information on energy consumption that is available immediately or remotely to energy suppliers and consumers;
- Easy to understand, prominent display unit which includes:
  - Costs in £/p,
  - Indicator of low/med/high use,
  - Comparison with historic/average consumption patterns,
  - Function to allow data to be accessed via PCs/mobile phones,
- Two-way communication between energy supplier and the meter to make it possible to switch tariffs, or pay as you go (prepayment) provisions, remotely;
- An internal memory to store consumption information and patterns;
- Export metering for micro-generators;
- Demand-side management options, such a tariff which charge more at peak-demand times of the day and less for off-peak times;
- Inactivity monitoring and , in gas, real time monitoring of gas leaks and carbon monoxide emissions; and
- Provide data to suppliers to ensure:
  - Correct and timely bills;
  - Information on patterns of use - improving forecasting and wholesale purchase;
  - Targeted advice of efficiency measures to customers.

In order to realise the benefits of improved metering the following characteristics will be probably needed:

- clear display ...
- an internal memory to store half-hourly data for at least a year
- a communication facility ...
- two-way communication ...
- ability to be upgraded ..."

3) Dutch Technical Standard for Smart Metering (NTA 8130), to be published January 2007

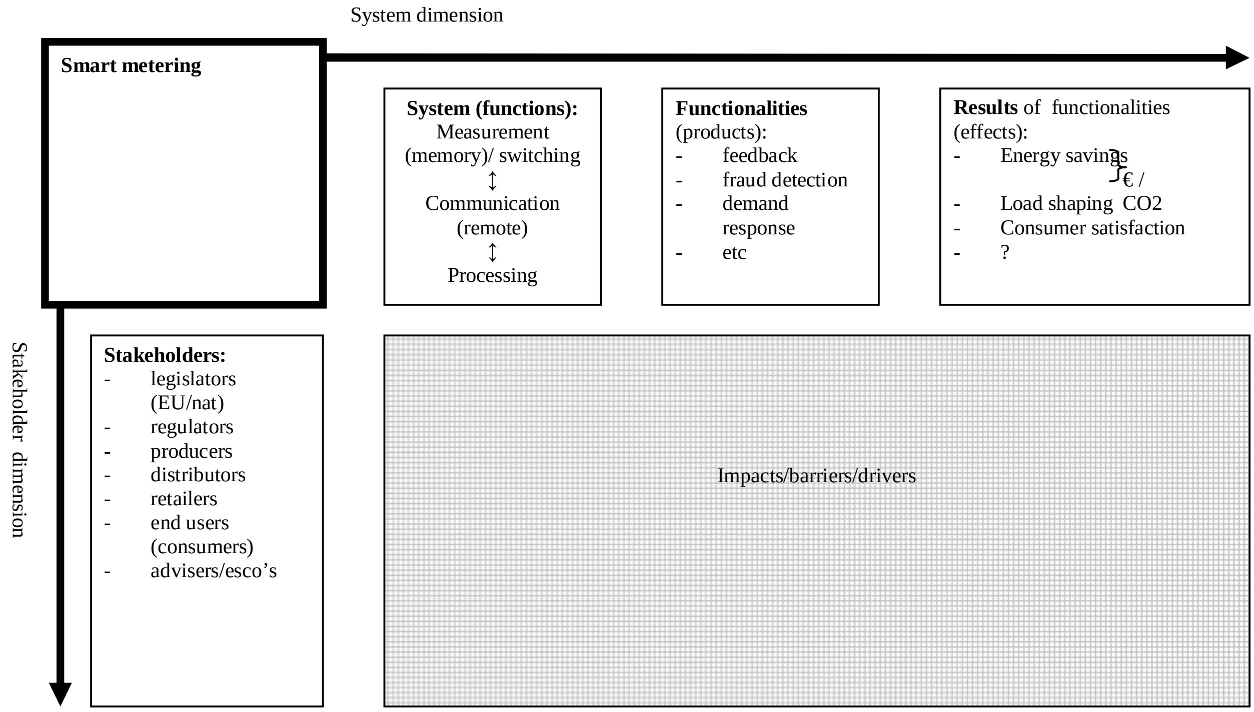
(According to Josco Kester, ECN) defines smart metering as follows:

Smart metering systems are supposed:

- to contribute to amelioration of administrative processes by generating periodically and on request real, distance readable meter values;
- to enable the supplier to promote towards his customers awareness of energy use and to stimulate energy saving;
- to be able to safely disconnect and reconnect at a distance of individual connections of electricity and gas;
- to be able to adjust at a distance the capacity of electricity connections collectively (e.g. in cases of power shortage) or individually (in case of non-payment)
- to enable the (retail) supplier of energy and/or water to use differentiated tariffs;
- to enable the delivery of energy after payment ('prepayment metering');
- to enable monitoring of the distribution grid.

In addition to this the systems should accommodate innovative developments and should use open protocols for communication.' . The above text is translated by Josco Kester from Dutch from: NTA 8130:2007 Minimum set of functions for metering of electricity, gas and thermal energy for domestic customers, page 2.

4) Figure by Hans-Paul Siderius, SenterNovem



5) The Carbon Trust in a recent document defined smart metering as;

(according to Nigel Orchard, Pilot Systems)

Smart meters can provide reliable and timely consumption data readily usable in an energy management programme to help reduce costs and associated carbon emissions. Such meters can also eliminate problems associated with estimated bills and the potential consequences of not being able to correctly forecast and manage energy budgets.

Although there is no universal definition, the following functions are required of a smart meter:

- Real time information on energy consumption that is available immediately or via some form of download to either or both energy suppliers and /or consumers;
- Two-way communication between energy suppliers and the meter to facilitate services such as tariff switching and the provision of pay as you go (pre-payment) systems;
- Inactivity monitoring and real time monitoring of gas leaks and carbon monoxide emissions;
- Record consumption half-hourly;
- An internal memory to store consumption information and patterns;
- Easy to understand, prominent display unit which includes:
    - o Costs in £/p,
    - o Indicator of low/med/high use
    - o Tips on how to reduce use,

  - o Comparison with historic/average consumption patterns,
  - o Compatibility with PCs/mobile phones,
- • Export metering for micro-generators;
- • Demand-side management options (for example tariffs which charge high prices for peak demand, but lower than average prices for off-peak use to encourage consumers not to use excessive energy during peak periods.)

Smart metering can thus be achieved by installing a new communication enabled fiscal meter which is capable of the above tasks. Alternatively, solutions are available to bypass replacement of the fiscal meter, including the use of sub-metering or bolt-on data readers and optical meter readers, both of which are capable of storing and transmitting half-hourly consumption data.

6) Endesa:

(according to Luis Diaz Saco, Endesa)

Smart Metering is the remote and automatic operation of meters and other devices to improve the efficiency of the electric system and quality of service. It implies a new relation model between the utility and its clients, using telecommunications to interchange information between the utility and the devices installed in every supply. Smart Metering will add value to the service, giving better information to the customers and optimizing the use of the demanded power and consumed energy.

A Smart Metering system is a set of elements that lets bidirectional communication between utility and its clients, and gives support for basic functions like reading of electric parameters, management of contracts and control of the demanded power. A Smart Meter is the part of the system installed in the side of the client.

7) ERA, the trade association for UK gas and electricity suppliers.

(according to Nigel Orchard, Pilot Systems)

Guidelines on defining a smart meter:

A system for metering any residential energy supply that:

- Measures consumption over representative periods to legal metrology requirements
- Stores measured data for multiple time periods
- Allows ready access to this data by consumers as well as by suppliers or their agents and at least one of the following functions:
- Provides analysis of the data and a local display of the data in a meaningful form to the consumer or as part of a smart housing solution.
- Transfers consumption data to the supplier or his agent for the purposes of accurate billing without requiring access to the home.
- Provides a payment facility for one or more supplies.

- Measures, and records information as to the continuity and quality of the supply and provides this and other data to the Distribution Network Operator for purposes of system operation, planning, and loss assessment.
- Permits remote control (e.g. interruption and restoration) of specific consumer circuits or equipment for the purposes of agreed load management.
- Allows display of price signals for different time periods as part of a cost reflective tariff for the purposes of demand response.
- Allows for remote change of tariff, debt or other rates for utility charging without requiring access to the home.

8) Definition of Smart Metering by EDV Energia (sent by Viktor Lopes)

A Smart Metering System is the remote and automatic operation of meters that lets the bidirectional communication between the DSOs and the consumers.

For us, the core and the more important functions are the following:

- End use energy management
- Smart Homes, home automation, remote control of appliances by costumer
- Energy saving
- Services for monitoring and improving energy efficiency of end use and dispersed generation, customer information feedback.
- Meter Management.
- Demand response for electricity market
- Load analysis, modelling and forecasting

The Smart Metering System secondary functions are the remaining functions.

We expect that these functionalities may be obtained using a structure which is constituted by Measurement, Communication and processing components.

9) Comment by Andrei Z. Morch regarding definition of Smart Metering: I believe we should identify what are the CORE and what are the OPTIONAL functions for Smart Metering.

I think we should keep in mind that implementation of additional functions increases both capital and operational costs for Smart Metering. It also increases several technical problems as interoperability, even though it is outside scope of the present project. Additionally, not all optional functions are universally relevant for each country.

The reason why I want to mention it is, that our Regulator is very concerned that DSOs (or other metering operators) may overly invest in functions, which will not be fully utilised later on. Our Regulator has done a survey of 113 DSOs in Norway. I enclose a slide with some results from the survey. They basically show that DSOs are using only the core functions: collection and transfer of metered data.

Functionality	Number of companies with available technology	Number of companies who uses the technology
Remote disconnection of single loads	73	20
Remote disconnection of total plants	62	16
Outage recording	45	6
Voltage monitoring	42	5
Alarm- and security services	28	0
Others	11	4

9 1. jan.

Comment on the comment by Pekka Koponen: Many industry experts and manufactures have in several occasions emphasised the fact that the added cost of many added functionalities is very small or even zero. The ENEL case is a good example of this. The total project cost per meter there is below the cost of poorly organised meter installation work only per meter in the Nordic countries. (In other words for that money we do not get a meter nor a system, just the installation work.) And the ENEL meters have quite much functionality. Visits or two at the meter location easily cost more than the smart meter. Specifications enabling mass market products bring the meter costs down. Design, approval and starting the production of hardware take time and money. Logistics get simpler, when there are less different models. Mass produced data processing and storage capacity do not cost much. Often removing functionality unnecessary in a certain environment will only increase the cost per meter by decreasing the number of similar meters produced, delivered and stored. Thus it should not be a major problem that there are unused functions. If even one of those functions will ever become necessary, having it in the meter will multiply pay back all the other unused functions.

Andrei Z Morch: In average, lifetime of Smart Meters, we have seen so far is about 10-15 years. By the time when these additional functions will be demanded the meters and the supporting infrastructure will have to be changed anyway. Back-compatibility of meters has been a very weak point. In reality the vendors cannot sufficiently handle even basic metering functions from meters, delivered 5 years ago (For example, Enermet AIM cannot handle meters, installed with Enermet Avalon. The same problem with Kamstrup EMS10 and Kamstrup EMS11).

I believe we should be cautious in our conclusions and recommendations. We have a lot of contradicting statements with different incentives behind them: several DSOs in Norway have been very sceptical to additional functions after they have experienced high investment and commissioning costs. Some others have opposite experience. The case of ENEL is also difficult. The story from independent sources is less positive.

10) Comment by Claudio Rochas, Ekodoma. I generally agree with the above definitions of smart meters and as well as with the final definition proposed for ESMA (Smart metering has the following features: (i) Automatic processing, transfer, management and utilisation of metering data. (ii) Automatic management of meters (iii) Data communication with meters (2-way, reliable, secure, open, standard, ...) (iv) Provides meaningful and timely consumption information to the relevant actors and their systems, including the energy consumer. (v) Supports services that improve the energy efficiency of the energy consumption and the energy system (generation, transmission, distribution and especially end-use).)

However, I would like to add as well as the following general points:

Smart metering is a “system” designed to change and improve in terms of simplification, transparency e promptness the relationship between DSO and clients.

From the client point of view, smart metering allows in a simple and fast way to:

- To control and know consumption information (kWh)
- To control and know the effective load (KW)
- To have the bill calculated based on the effective energy consumption, without advance or balance payments
- To have the possibility to easily activate or modify the contract with the DSO.
- To reduce waiting time for to open or close the contract with the DSO.
- To reduce or even abolish the “unpleasant” visits of the utility personnel to the meters.

From the utility point of view, smart metering allows or enhance:

- Automatic management of meters, data communication with meters, Automatic processing, Demand side management, etc…

11) The following definition from the USA was sent by J. Parsons:

A bill has been introduced in the U.S. House of Representatives aimed at creating a special tax incentive for the installation of smart meters. Entitled the Energy Conservation through ‘Smart Meters’ Act, the bill seeks to amend the Internal Revenue Code of 1986 to provide a five year applicable recovery period for the depreciation of “qualified energy management devices”. For the purposes of the Act, an “energy management device” is defined as "any time based meter and related communication equipment which is capable of being used by the taxpayer as part of a system that:

(i) measures and records electricity usage data on a time differentiated basis in at least 24 separate time segments per day,

(ii) provides for the exchange of information between supplier or provider and the customer's energy management device in support of timebased rates or other forms of demand response,

and

(iii) provides data to such supplier or provider so that the supplier or provider can provide energy usage information to customers electronically."

12) Elexon SVG/56/006 dated Sept 2005:

The term "Smart Metering" can refer to a broad range of advanced metering and retrieval technologies. For the purposes of this paper the term "Smart Metering" refers to the types of product features outlined below..........

Automatic Meter Reading (AMR). One way communication where the meters can be read remotely, ...

Automatic Meter Management(AMM). Two way communication where, in addition to AMR, the meters can typically: monitor and detect fraud; enable remote disconnection or load limiting; facilitate remote tariff changes; and display costs, energy used, energy efficiency and real time tariff information.

Interval Metering with Automatic Meter Management AMM (IM). In addition to AMM, the meters can record and store more detailed usage information. Electricity consumption is captured in frequent increments, such as quarter or half hourly intervals. This data can be stored in the meter and retrieved remotely as required (e.g. daily or monthly).

13) Industry Metering Advisory Group, March 2006 defines Smart Metering Systems:

A system for metering any residential energy or water supplies that:

A Measures consumption over representative periods of legal metrology requirements
B Stores measured data for multiple time periods
C Allows ready access to this data by consumers as well as by suppliers or their agents

and has at least one of the following functions:

i. Provides analysis of the data and a local display of the data in a meaningful form to the consumer or as part of a smart house solution
ii. Transfers consumption data to the supplier or his agent for the purposes of accurate billing without requiring access to the home.
iii. Provides a payment facility for one or more supplies.

iv. Measures, and records information as to the continuity and quality of the supply and provides this and other data to the Distribution Network Operator for purposes of system operation, planning, and loss assessment.
v. Permits remote control (e.g. interruption and restoration) of specific consumer circuits or equipment for the purposes of agreed load management.
vi. Allows display of price signals for different time periods as part of cost reflective tariff for the purposes of demand response.
vii. Allows for remote change of tariff, debt or other rates for utility charging without requiring access to the home.

And, where a consumer has microgenerator equipment installed:

- Provides a facility to measure energy export and/or generation, where required for official purposes.

14) NERA Economic Consulting in Cost Benefit Analysis of Smart Metering and Direct Load Control, Phase 1 Overview (Sydney, 17 September 2007) :

The functionalities that we have assumed to be core for all smart meters are:

- half-hourly consumption measurement and recording;
- weekly remote reading;
- local reading via both a hand held device and a visual display on the meter;
- secure transmission of data from the meter;
- tamper detection;
- remote time clock synchronisation; and
- load management at meters through a dedicated control circuit, consistent with current jurisdictional arrangements.

The Phase 1 assessment has focused on the incremental costs and benefits associated with adding additional functionalities to this 'core' set.

15) Advanced Metering for Energy Supply in Australia, 17 July 2007, report prepared for the Total Environment Centre by Energy Futures Australia:

Smart meters include, in addition to interval metering capability, one-way or two-way communication between the energy supplier and the meter.