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Survey of Regulatory and Technological Developments Concerning Smart Metering in the European Union Electricity Market

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Abstract

Smart metering is a crucial factor for the efficient functioning of the Internal Electricity Market, as well as for the successful implementation of European Union policies related to energy efficiency, renewable energy and security of supply.

The report first outlines the potential benefits of smart meters for consumers, suppliers, metering companies, distribution network operators and public interest. Next the report provides a short overview of the legal framework governing metering activities in Europe, as well as a review of smart metering policies, a summary of regulatory and legislative tools and an analysis of cases in selected countries.

Drawing from the experiences to date, the report concludes with a set of recommendations for policy makers to consider when developing a smart metering programme and the regulatory approaches that could be adopted at national and/or EU level to encourage compatibility of smart metering solutions and to accelerate implementation of smart meters and smart grids.

Keywords

smart metering, demand response, electricity markets, regulation

Smart metering:

The 21st century contribution to more efficient electricity systems

In the 1880s only carbon-filament incandescent lamps were available, designed for a voltage of around 100 volts. Later metal filament lamps became feasible. In 1899, the Berliner Elektrizitäts-Werk (BEW), a Berlin electrical utility, decided to greatly increase its distribution capacity by switching to 220 volt nominal distribution, taking advantage of the higher voltage capability of metal filament lamps. The company was able to offset the cost of converting the customer's equipment by the resulting saving in distribution conductors cost. This became the model for electrical distribution in Germany and the rest of Europe and the 220-volt (later 230-volt) system became common.

http://en.wikipedia.org/wiki/Mains_electricity#_note-6

Introduction

Smart metering is a crucial factor for the efficient functioning of the Internal Electricity Market, as well as for the successful implementation of European Union (EU) policies related to energy efficiency, renewable energy and security of supply.

Smart meters are the visible face of a new information and communication technology (ICT) infrastructure being introduced in electricity systems. This modern ICT infrastructure allows electricity consumers to play a more active role in the functioning of electricity markets ("demand response") and distribution networks to play a more active role in the functioning of electricity systems—i.e. distribution networks become "smart grids". This new infrastructure should enable *inter alia*:

- new contractual arrangements between consumers and suppliers taking into account the technical possibility of effective remote demand-side management, either by the client itself or by it's supplier;
- easy and cost-effective consumer switching throughout Europe;
- efficient integration of decentralized, renewable sources of electricity generation into system operation, as well as into commercial strategies of electricity suppliers;
- more efficient distribution network planning and operation leading to more efficient investment, reduced losses and better quality of service.

As pointed out by the International Energy Agency, "In a 21st century power system, it would be appropriate to move to metering systems that can enable much greater real-time information for demand response and other end-use energy services"[1].

Current developments in Europe are characterized by a lack of technical and regulatory harmonization, thus leading to a patchwork of national (and sometimes even infra-national) solutions. Very often this situation creates unnecessary extra costs, reduces potential economies of scale that should benefit all consumers and introduces new barriers to full integration of the EU electricity market. Therefore, some degree of harmonization is needed in order to facilitate the quick and cost-effective introduction of smart metering in the European electricity market. Harmonization does not mean, however, that one single technological solution should be imposed. Given the existing diversity of available technologies, harmonization should be considered at the functional level, leaving to manufacturers, metering companies, electricity suppliers and consumers the freedom to adopt different (competing) technical solutions, as long as they are compatible with the efficient functioning of the Internal Electricity Market.

The main purpose of this report is to present a state of play of electricity smart metering in Europe. It builds upon and updates a Status Review study carried out by the European Regulators' Group for Electricity and Gas (ERGEG) and the European Commission in spring 2006[2] which examined the regulatory experiences with smart metering in Europe. Drawing from these experiences, as well as from international experiences, in particular in the United States of America (USA), and recent market and technology developments, the present report concludes offering some guidance to policy makers and regulatory authorities contemplating a smart metering programme with a focus on regulatory approaches which would avoid unnecessary costs and barriers thus facilitating the potential benefits to be realized in Europe.

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1 IEA. "The power to choose - demand response in liberalised electricity markets". 2003

2 ERGEG. "Smart metering with a focus on electricity regulation". October 2007. See www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/CEER_ERGEG_PAPERS/2007/Positions/E07-RMF-04-03_SmartMetering_final.pdf

The report first outlines the potential benefits of smart meters for consumers, suppliers, metering companies and distribution network operators. Smart meters are also useful tools to implement several energy policy measures related to environmental protection (e.g. facilitating energy efficiency, demand side management and micro-generation), competitiveness and security of supply, as well as furthering government policies in a number of areas (e.g. protection of vulnerable customers). The potential benefits depend not only on the type of technology and its functionality but also upon the systems with which the smart meter must integrate (e.g. data collection and processing, network management), other policies in place (e.g. consumer awareness and availability of time-of-use tariffs) and a host of other factors (e.g. price responsiveness of consumers).

Next the report provides a short overview of the legal framework governing metering activities in Europe as this has a bearing on the policy options available for implementing a smart metering programme.

This is followed by a review of smart metering policies, a summary of regulatory and legislative tools and an analysis of cases in selected countries with (current or planned) public policies aimed at fostering the adoption of smart meters or where companies have voluntarily initiated smart metering projects. Special emphasis is given to those regulatory aspects that facilitate or hinder openness and interoperability of the different technologies and systems being implemented, as well as to the definition of minimum functional requirements.

Drawing from the experiences to date, the report concludes with a set of guidelines for policy makers to consider when developing a smart metering programme and the regulatory approaches that could be adopted at national and/or EU level to encourage compatibility of smart metering solutions and to accelerate implementation of smart meters and smart grids.

1. Potential benefits of smart metering

1.1 Smart metering is not only about remote meter reading

Before outlining the potential benefits of smart meters, it is useful to define what is meant. Smart meters are modern, innovative electronic devices capable of offering consumers, suppliers, distribution network operators, generators and regulators a wide range of useful information, enabling the introduction of new energy services and new contractual arrangements.

Traditionally, electricity consumption in households[3] was measured with electromechanical devices called Ferraris meters: basically, an aluminum disk rotating in a magnetic field in such a way that the disk speed is proportional to electricity consumption[4]. The disk is mechanically connected to a set of gear wheels that display the total amount of electricity consumed since the meter was installed (i.e., the cumulated consumption value). For billing purposes, electricity consumption over a given time period (typically between one month and one year) is calculated by reading the meter and subtracting the value registered the previous time the meter was read.

3 In scientific terms, the variable used to bill households is active power, and the most common unit used is the kilowatt hour. That is the reason why, sometimes, household electricity meters are called watt-hour meters. Large electricity consumers usually are subject to measurements other than active power, namely reactive power.

4 The Italian scientist Galileo Ferraris made his important discovery about electromechanical induction in 1885 and in 1898 commercial electricity meters were introduced by several utilities in the USA. Meter manufacturers adopted very different designs which implied high maintenance and replacement costs for utilities. Electromechanical meter standardization started in the 1930s.

Electromechanical meters are robust, reliable[5] and relatively inexpensive[6] but they require human intervention to collect (either the consumer or utility' staff must go and read), to communicate and to store data. Moreover, the aggregated data does not provide detailed information about consumption behavior (how much electricity is used during the hours of the day, the days of the week, etc.), although some more sophisticated (and more expensive) meters can display cumulated values corresponding to different time periods (e.g. day and night).

Finally, electromechanical meters just measure total electricity consumption: for instance, they are not able to register electricity interruptions or deviations from nominal voltage and they do not allow acting upon consumption (for instance, transiently or permanently limiting maximum power).

Over the last years, performance of electronic meters has steadily increased and prices have decreased, as shown in Figures 1 and 2[7]. Therefore, electronic meters are replacing electro-mechanical meters in many countries[8]: In 2006, smart or advanced meters represented 86% of total installed meters in Italy, 21% in Sweden, 18% in Finland[9], 53% in Pennsylvania, 40% in Wisconsin and 21% in

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5 However, they need to be periodically tested since their behavior may be affected by several types of errors (see www.usbr.gov/power/data/fist/fist3_10/vol3-10.pdf):

> **"6.3 SOURCES OF METER ERRORS**. Aside from the inherent errors due to variations in temperature, frequency, etc., which are factors of design, the most common causes of error within a meter are listed below and may be detected by inspection and corrected.
>
> **6.3.1. Common causes.**
> (1) Dirt (on the disk; in the air gaps).
> (2) Magnetic particles (in the permanent-magnet air gaps).
> (3) Gummy oil and/or dirt in bearings.
> (4) Broken jewels.
> (5) Disk rubbing in air gap.
> (6) Improper mesh of gears or dirty gearing.
> (7) Improperly adjusted bearings.
> (8) Vibration of the meter mount-ing.
> (9) Creeping.
>
> With the exception of (8) and (9) above, it will be noted that all defects listed introduce friction and will cause the meter to register "slow."
>
> **6.3.2. Other causes.** -
> (1) External magnetic fields which may add to, or subtract from, the normal meter magnetic flux.
> (2) Overloads and short circuits. The effect of overloads and short circuits may be to alter the magnetization of the brake magnets, to magnetize adjacent masses of iron, and in general to disarrange the parts.
> (3) Short-circuited turns in meter coils.
>
> **6.3.3. External causes.** - Some of the sources of error which may occur outside the meter itself are:
> (1) Instrument transformer phase-angle and ratio errors.
> (2) Improper connections such as cross-phasing and reversed polarity.
> (3) Broken or high-resistance connections and short circuits in meter wiring and test blocks, blown potential fuses, short-circuiting switches inadvertently closed or left closed, etc.
> (4) Improperly calibrated or poorly maintained rotating standards."

6 However, one should keep in mind that in practical terms electromechanical meters are small induction motors. Although their individual consumption is small (about 2 W), the total amount of energy dissipated in electromechanical meters is considerable. 250 million customers (electromechanical meters) require a permanent installed capacity of 500 MW – the equivalent of one large power plant.

7 FERC. "Assessment of demand response & advanced metering". August 2006. See www.ferc.gov/legal/staff-reports/demand-response.pdf

8 In the 1980s some manufacturers started offering hybrid meters: the rotating disk was still the core, but digital displays and registers were introduced. In the 1990s, full electronic meters became commercially available and some manufacturers started phasing out electromechanical meters.

9 ERGEG. "Smart metering with a focus on electricity regulation". October 2007. See www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/CEER_ERGEG_PAPERS/2007/Positions/E07-RMF-04-03_SmartMetering_final.pdf

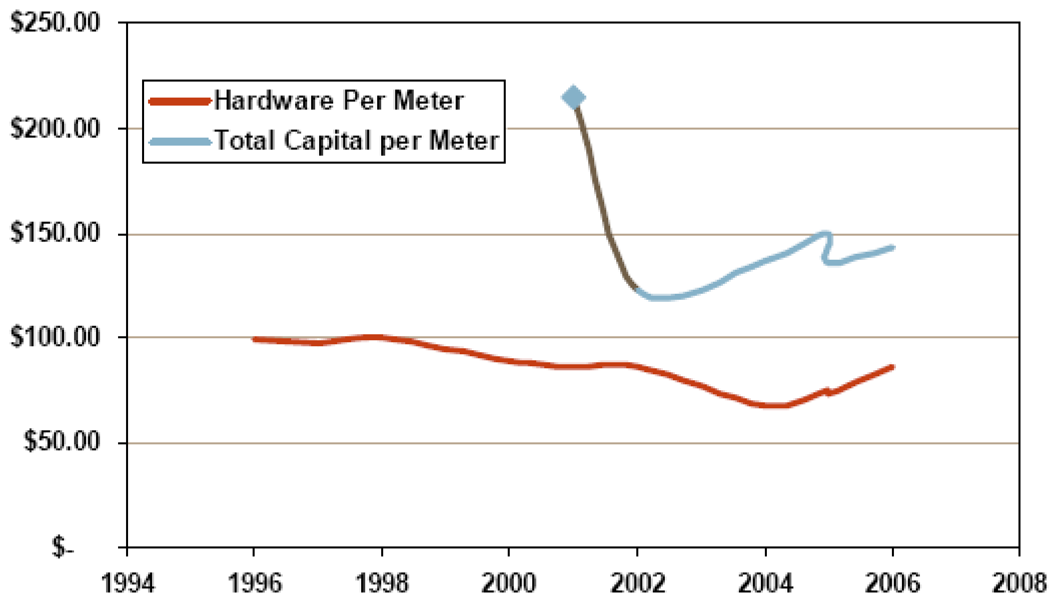
Connecticut (in the USA, the average penetration of smart metering was about 6% of total installed electric meters)[10].

Fig. 1 Smart meter cost benchmark in the USA.

Utility	Year	Meters (millions)	Hardware (millions)	Total Capital (millions)	Hardware per meter	Total Capital per Meter
DLCo	1996	0.6	$60	-	$99.23	-
Virginia Power	1997	0.5	$44	-	$97.78	-
PREPA	1998	1.3	$130	-	$100.00	-
ENEL	2000	30.0	$2,673	-	$89.10	-
JEA	2001	0.7	-	$150		$214.29
PPL	2002	1.3	$112	$160	$86.15	$123.08
Bangor Hydro	2004	0.1	$7.50	$15.0	$68.18	$136.36
TXU	2005	0.3	$19	$38	$75.60	$150.00
PG&E	2005	9.8	$721	$1,328	$73.57	$135.48
SDG&E	2006	2.3	$199	$329	$86.43	$143.04

Source: Utilipoint International

Fig. 2 Evolution of smart meter costs in the USA.



Source: UtiliPoint International

10 FERC. "Assessment of demand response & advanced metering". August 2006. See www.ferc.gov/legal/staff-reports/demand-response.pdf

Electronic meters are more accurate than electromechanical meters, have lower energy consumption (typically 0.5 W against 2 W) and can be easily combined with digital displays and electronic local storage units providing the consumer with more and more accurate information about his or her own consumption. With electronic meters, it is easy and cost-effective to monitor variables other than just active power (the only variable registered by electromechanical meters in households), such as: reactive power, power factor, apparent power, current harmonics, maximum power, etc.. These variables can be used for several purposes *inter alia*: to shape new contractual arrangements inducing more efficient consumer behavior, to define new, more cost-reflective network tariffs, to establish new regulatory incentives/penalties, etc..

Moreover, electronic meters can also be easily combined with modern communication technologies thus enabling cost-effective remote meter reading. Several communication technologies have been used to transmit data from individual consumers' meters to a centralized data base: electricity lines (so-called power line carrier or PLC technology), fixed line and mobile telephone, internet, radio waves, etc.

Automatic Meter Reading (AMR) is a clear improvement over the past metering technology. AMR provides a new tool of network management (additional to the traditional SCADA and distribution management system). For example, automatic monitoring of faults traditionally did not occur at low-voltage distribution level—but instead only at medium voltage level. Any information to the control centre on faults depended on customer calls. With AMR, if a fuse blows or a conductor is broken this information flow occurs automatically. This has a number of advantages for network operation such as being able to quickly locate and if necessary isolate the fault, as well as providing accurate interruption and voltage quality data (voltage dips, voltage level) which can be used to better serve customers and to improve network planning. However, AMR is a one-way system, just collecting data from the meters.

Automated Meter Management (AMM) can be defined as intelligent metering services based on two-way data communication. It broadens the scope of AMR beyond just meter readings with additional features enabled by two-way real-time data communication between customers, suppliers and distribution network operators. In this sense, the smart meter becomes a gateway for many functions and multiple service providers, offering potential benefits at many different stages of the electricity supply chain.

Smart metering is a generic term for Automated Meter Management (AMM) and Automatic Meter Reading (AMR). Sometimes the expression Advanced Metering Infrastructure (AMI) is also used.

While useful to start with the analysis of benefits to customers, depending on its applications, smart metering has a range of other possible benefits which are categorized below.

1.2 Potential benefits to consumers

Smart metering systems may benefit consumers in a variety of ways. The mere replacement of electromechanical meters by smart meters gives electricity consumers more information, thus enabling them to make better decisions (e.g. choosing the most convenient supplier or choosing when to connect/disconnect some devices). However, the potential benefits of smart meters may be considerably amplified if appropriate regulatory measures (e.g. time-of-use network tariffs) and appropriate additional technologies (e.g. device controllers) are introduced. The following list describes some potential benefits to consumers:

- **Customer awareness and energy savings.** Smart meters can record how much electricity is used during different periods of the day (e.g. hourly readings or peak/off-peak); they even can show on a display or on a computer screen the instantaneous electricity consumption, thus allowing consumers to visualize the impact of individual appliances on their electricity bill. The closer to real time that accurate consumption data is made available to the consumer, the more likely consumption behaviour changes. This is far more effective than the current standard situation where consumption is often not considered until the day the bill arrives (i.e. months later), and then forgotten. With appropriate available software, it is also possible (if necessary complementary information is available) to translate physical values (kWh) into monetary or CO_2 emission values, showing consumers in real-time how much they are going to pay or how much CO_2 emissions their electricity consumption is responsible for. Conversely, the software can indicate to consumers how much they would spare (in monetary terms or CO_2 emissions) if they changed their consumption behavior in a sustained way. Energy consumers are increasingly aware of the importance of energy efficiency for their own benefit (lower energy bills) and for the benefit of society (less greenhouse gas emissions, increased security of supply). However, several inquiries have demonstrated the lack of clear information to consumers[11].

- **More accurate meter reading, billing**. With smart meters, bills are based on real rather than estimated consumption. AMR dispenses with the necessity of waiting in for the meter reader or of having to send in meter readings. This generates added benefits such as improved customer satisfaction resulting in fewer customer complaints, especially when conciliation between estimated and real consumption occurs after several months. It is also possible for a customer to agree with the respective supplier how frequently billing takes place and to get a bill on demand (e.g. when moving from one home to another). Smart meters facilitate contractual changes - e.g. enabling remote activation/de-activation, dispensing with the necessity of waiting for the utility staff.
- **Better service quality.** Availability of individual service quality measurements (e.g. number and duration of network outages, voltage deviations from nominal value, etc.) allows regulators to design new incentives/penalties aimed at improving the performance of distribution network operators and automatically compensating customers suffering from particularly poor technical quality of service.
- **Greater tariff variety and flexibility.** Smart meters (by arming consumers with better, timely information about their energy use) when combined with time-of-use tariffs allow customers to better manage their energy consumption and thus offer them savings on their electricity bills. Postponing certain usage (e.g. dishwasher) to cheaper periods not only offers customers cost savings but may also generate energy savings if sufficient demand is shifted to off-peak times. Smart meters can also facilitate pre-payment options (widely used for mobile phones) which allow customers to pay in advance and hence to better manage their budgets.
- **Improved conditions for vulnerable customers.** Smart meters allow suppliers to better communicate with vulnerable customers, e.g. sending timely warning messages, and to avoid abrupt disconnection through phased actions[12].

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11 See for instance a recent study performed in Italy for ENEL - www.enel.it/attivita/ambiente/energy/politiche91_hp/politiche91/index.asp

12 This point is well illustrated by the Italian energy regulatory authority (AEEG):

> "The Authority does not monitor the number of disconnections for late payment, but it does monitor the number of requests for reconnection following suspension for nonpayment which reached 862,967 in the electricity in 2006 (low voltage clients), while in the gas sector there were 60,597 (end clients supplied at low pressure). The number of requests for reconnection following suspension for non payment in the electricity sector has risen in recent years (there were 310,540 in 2004) following the introduction of remote managed meters which permit operators to apply, as an alternative to disconnection, a drastic reduction of the voltage supplied to a so called "vital minimum" level (approximately 0.5 kW). This practice, recommended by the Authority to better protect consumers, minimises the effective damage to the client while awaiting regularisation of the account."

> Autorità per l'energia elettrica e il gas. Annual report to the European Commission on regulatory activities and the state of services in the electricity and gas sectors. July 2007 (p. 76). www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/NATIONAL_REPORTS/NR_2007/NR_En/E07_NR_Italy-EN.pdf

- **Easier comparability of offers.** Being better aware of exactly what their consumption has been during the past year(s), customers are better informed when comparing tariffs of competing suppliers. Alternatively, customers can ask for offers from different suppliers based on their real, historical consumption[13]. ERGEG examining the obstacles to switching, underlined 3 key areas for creating the conditions necessary for consumers to make informed choices; (i) that consumers are able to get comparable price information (ii) that relevant and applicable price information has to be publicly available and (iii) that consumers are able to compare new price offers with their existing contracts[14].
- **Easier to change supplier.** Customers will be able to switch supplier easily as meters can be read at any time on request, thus shortening delays for switching to take effect (see Table 1 on next page[15]).

  According to ERGEG[16] "it is preferable that the meter is read in connection with the switch, as this is an importance reference for settlement of the former contract". In this regard, ERGEG points to the benefits of smart metering in stating "It may be assumed that introducing automatic meter reading will dramatically improve the time and efficiency of the switching procedure". However, ERGEG goes on to underline that "advanced meters which are automatically read should not be a prerequisite for the customer's eligibility to switch. Metering should not be an obstacle to switching. In a dynamic retail market with high mobility, however, it is recommended that the meters are read upon switching".

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13 The importance of this point is illustrated by the following statements by the Austrian regulatory authority (E-Control) and by the Hungarian regulatory authority (HEO), respectively:

> "After considering ways of streamlining the switching process E-Control proposed the introduction of a common metering point database for all Austrian electricity consumers, which could be used to manage supplier transfers. However the opposition of the system operators and their owners prevented the inclusion of this scheme in the final draft of the bill. Negotiations were therefore held with the system operators on accelerating the switching process by amending the market rules. The talks led to a shortening of the process from eight to six weeks.
>
> Under the previous market rules, system operators were obliged to send suppliers customers' metered consumption data at intervals corresponding to those for meter reading (normally annual). The rules only required system operators to transmit data on the total consumption of customers' installations to new suppliers. This meant that the latter were at a disadvantage against subsidiaries of integrated companies, since they received no information about consumption per tariff period where meters capable of recording demand separately during different rating periods (e. g. high and low rate periods) were in place. The new suppliers were thus unable to quote a different energy price for each tariff period. The market rules were amended to ensure that all suppliers are given impartial treatment with regard to metering data, and since the autumn of 2006 system operators have been required to provide them with separate consumption data in a standardised format for each tariff counter."

www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/NATIONAL_REPORTS/NR_2007/NR_En/E07_NR_Austria-EN.pdf (see p. 24).

> "Real competition only takes place only for energy intensive large consumers (over 70 GWh annual consumption), while the suppliers did not press for the business of medium-sized (between 50 MWh and 2 GWh) and small consumers (under 50 MWh yearly consumption). Large consumers (between 2 GWh and 70 GWh yearly consumption) received market offers easily in case they owned real time consumption meter."

www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/NATIONAL_REPORTS/NR_2007/NR_En/E07_NR_Hungary-EN_v2.doc (see p. 29).

14 ERGEG. "Obstacles to supplier switching in the electricity retail market – Guidelines for Good Practice and Status Review". April 2008,
www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/CEER_ERGEG_PAPERS/2008/GGP/E07-RMF-06-03_switching%20electricity%20GGP%20status%20review_10.pdf

15 EURELECTRIC. Report on customer switching in Europe. March 2003.

16 ERGEG. "Obstacles to supplier switching in the electricity retail market – Guidelines for Good Practice and Status Review". April 2008,

Meter reading at switching is a problem in many countries, as illustrated in a number of the Annual Reports of individual regulatory authorities to the European Commission[17].

Table 1 Delays for switch to take effect

Country	Delays for switch to take effect
Cyprus	
Czech Republic	7 – 14 – 30 days depending on metering
Denmark	1 month minimum
Finland	2 weeks
France	2 weeks
Germany	1 month minimum
Hungary	Forthcoming code of supply
Ireland	16 days (up to 60 days)
Netherlands	5 days
Norway	3-5 weeks
Poland	Not yet defined
Portugal	15 days
Spain	15 / 30 days (depending on meter reading)
Sweden	30 days
United Kingdom	Minimum 1 day – max 28 days

- **Increased competition among suppliers.** Prices should become more competitive (and related services improved) as suppliers are able to offer customized contracts and added-value services, for instance selling "energy packages" that customers can manage (e.g. deciding when to consume, reselling power, etc.).
  With smart metering, competition can be introduced more generally at the service level and not only at price level.
- **Ability to manage consumption.** If individual devices are able to communicate with the smart meter, AMM allows customers or their suppliers to remotely control these devices. For instance, freezers, air conditioners or heating devices could be remotely disconnected for a certain period of time during peak hours, when spot prices increase above a certain level or in case of unexpected generation or network outages. Customers with demand response capability are rewarded either through lower average prices or through payments whenever they are asked to reduce demand.

  Thanks to new information and communication technologies, customers may become active masters of energy consumption, instead of being passive slaves of their energy consuming devices.

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17 For example, this statement by the Dutch regulatory authority (DTe):

> "In the 2006 /2007 period the main problem with switching was/is that the majority of switches (in the vicinity of 70% - 80%) are based on meter estimates instead of actual meter readings. This results in consumers not recognising their final settlement bill with the old supplier. This in result leads to many complaints and requests for corrected bills."

Annual Report by the Office of Energy Regulation (DTe) to the European Commission. www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/NATIONAL_REPORTS/NR_2007/NR_En/E07_NR_Netherlands-EN.doc (see p. 17).

A similar situation is reported by the French regulatory authority (CRE):

> "Some DSOs impose additional obligations on their customers: some systematically demand the "certificate for switching supplier", signed by the customer, from the future supplier, others carry out a special meter reading, invoiced to the future supplier."

www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/NATIONAL_REPORTS/NR_2007/NR_En/E07_NR_France-EN.pdf

As pointed out by the International Energy Agency, “Low price elasticities of demand for electricity are mainly the result of poor incentives and little ability for consumers to control their demand in today’s electricity market. In enabled markets, elasticity is high.” and “while price fluctuations are intrinsic to well-functioning markets, these can be reduced by encouraging greater response of demand to prices”[18].

- **Ability to manage micro-generation.** (e.g. combined heat and power facility, photovoltaic plant) or heat pumps without requiring new metering arrangements. Thanks to smart meters the producer/consumer can monitor and control the fulfillment of certain technical and/or economic requirements (this is particularly important in the case of heat pumps).
- **Potential for additional devices to be attached and smarter homes.** This could range from devices which also allow gas or water to be read through to domotic applications and new business innovations which may result in the electricity smart meter being the gateway to smarter homes, if it becomes a hub for home (or office) controls and security management.

1.3 Potential benefits to suppliers

In principle, where the metering market is liberalized and suppliers have the freedom to offer customers different metering solutions, the potential benefit for suppliers is higher since there is more scope for differentiation (e.g. meter design, specific tariffs, etc.). If meters are owned by the distribution network operator, the scope for differentiation between suppliers depends on the degree of flexibility provided by the metering technology adopted.

Smart meters offer suppliers several advantages, such as:

- **Pricing options.** The possibility of better knowing the consumption pattern of individual customers, with their permission, gives suppliers the opportunity to target them with customized contracts. These contracts may offer different electricity prices that apply at different times of the day, contemplate demand response, etc.
- **Potential for on-selling** related energy management services. The increased knowledge about the end-customers consumption behaviour presents an opportunity to develop new services aiming at helping the customer become more energy efficient.
- **Easier change of supplier process** as automation of meter reads naturally increases the speed of the process.
- **Fewer bill complaints** due to more accurate billing, thus reducing back-office costs in terms of customer service centre and less re-issuing of bills.
- **Fewer bad debts** as there is no longer any need to gain access to premises (not just for meter reading but also for energising/de-energising, etc.).
- **Better portfolio management.** With smart meters, suppliers are charged according to the real consumption of their clients, instead of standard load profiles. This enables suppliers to optimize wholesale power purchases. On the other hand, aggregating a critical mass of demand responsive customers enables suppliers to further reduce wholesale energy costs and even, if they so wish, to participate in balancing and reserve markets, earning extra profits.

1.4 Potential benefits to distribution network operators

Smart metering, when widely deployed, enables better information on the low voltage distribution network offering a range of potential savings to distribution operators. System-wide benefits derive from optimizing distribution operations, better reliability and the ways in which smart metering

18 IEA. “The power to choose - demand response in liberalised electricity markets”. 2003

support outage detection and reduction of restoration times, thus improving quality of service. Improved information at distribution level further provides an opportunity for less network losses and better investment planning.

- **Identification of fault locations.** Rather than the customer having to call to inform DSO/supplier when the power is out, with smart meters the utility automatically knows where the power is out and can dispatch crews to restore it immediately. Moreover, the distribution network operator can inform the concerned customers about the incident through internet/radio/SMS, thus improving customer satisfaction and avoiding typical situations of call center saturation.
- **Faster restoration times** provide an obvious benefit to consumers and savings to the distributor from reduced costs of more accurate dispatching of crews.
- **Service quality improvements.** The reward is potentially greater if the distribution network operator is subject to regulatory performance-based criteria such as number and duration of outages[19] or is subject to penalties/incentives for compliance with standards such as restoration times or amount of non-delivered energy.
- **Improved detection of network losses and theft.** Smart meters provide more accurate information about the location of losses and theft. (For some companies in Sweden and Italy network losses were key factors in installing smart meters).
- **Grid voltage and phase monitoring.** This can lead to improvements in voltage stability and system reliability.
- **Better network asset management and efficient infrastructure.** The availability of real-time, accurate and comprehensive information (voltages, loads, stressing, losses) generated by smart metering on the whole low-voltage network enables optimization of distribution network operation. Accurate information (load data on grid connection, load profiles over time, maximum loads and load distribution and power quality) also improves investment planning at distribution level generally. Such information can be used both for new investments in infrastructure (helping to facilitate more distributed generation) as well as for network reinforcements.

1.5 Potential benefits to metering companies

In most EU Member States meter reading is performed by distribution network operators. However, independent metering companies already exist or will be introduced in some Member States. Key operational savings for metering companies come from reduced meter reading costs and other way in which smart metering technology replaces labour costs, and facilitates contractual changes (e.g. meter activation/deactivation). Benefits also result from improved processes and fewer errors in meter management.

- **Efficient meter reading.** Operational savings derive from eliminating labour costs for manual meter reads. Smart meters also allow more frequent meter reads and improve meter reading accuracy, thus reducing meter disputes.
- **Remote activation/deactivation/maintenance.** Operational savings also derive from remote signals dispensing with the need for physical visits to premises to activate/deactivate and remote maintenance which does not require the customer's presence. Some countries (e.g. Italy and The Netherlands) plan to use smart metering for the better management of bad debts through remote reduction of the available power, followed by remote disconnection if the customer doesn't pay.

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19 Long interruptions are generally taken to be customer minutes lost of greater than 3 minutes. With smart metering, the outage in a single premise is known immediately, thus potentially decreasing the statistics for outages.

1.6 Potential benefits to the public interest

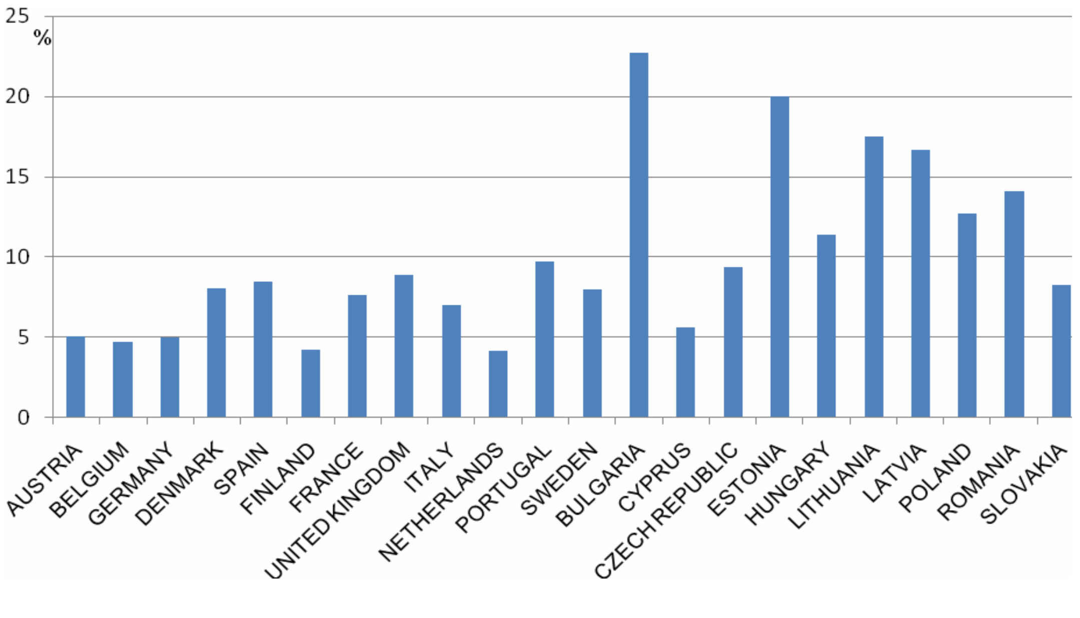
1.6.1 Improving energy efficiency

Smart metering is one technology where end-use energy efficiency can be encouraged, and thus result in reduced greenhouse gas emissions. A smart meter (depending on the type of device) gives consumers clear and comprehensive information about their energy consumption. Arming them with better information, can help consumers become more energy efficient. However, installing smart meters will, by itself, do nothing to save energy. Energy savings will only be achieved if installing the meters results in consumers actually changing their behaviour so as to use less energy in total. Demand response can be performed directly by the consumer or indirectly by the supplier or by a third party (see Section 1.6.2 below).

The key benefit is the potential carbon savings from households reducing their energy consumption as a result of smart metering. There can also be further savings to the household if they are demand responsive to time-of-use tariffs, and shift part of their consumption from peak (when the least efficient power plants are called into operation) to off-peak times.

Smart meters also provide useful information to distribution network operators. This information can be used, i.a., to better manage networks thus reducing network losses. In most countries, electricity network losses represent the largest electricity "consumer". As shown in Figure 3, efficiency of network operation varies considerably from country to country and in many countries there is a substantial potential for network loss reductions.

Fig. 3 Network electricity losses related to final electricity consumption in different European countries, 2003



Source: Data from EURELECTRIC http://www.eurelectric.org/CatPub/Document.aspx?FolderID=1540&DocumentID=18870

1.6.2 Enabling increased penetration of renewable electricity generation

The increased penetration of intermittent sources of electricity generation based on renewable resources such as wind and sun requires careful analysis in terms of power system planning and operation, especially as regards reserve capacities. Although forecasting models of renewable electricity generation have improved during the last years and will continue to improve, there will always be an inherent operational uncertainty about the availability of wind and solar based electricity generation[20].

In order to overcome this uncertainty, three different technical solutions may be adopted:

- Storage
- Redundant capacity
- Demand response

Although several electricity storage technologies have been proposed and tested (batteries, super capacitors, fuel cells, superconductivity, flywheels, etc.), currently only two technologies are able to provide significant energy storage capacity (say, above 100 MW): pumped storage hydropower and compressed air. However, the application of these technologies clearly depends on geography and geology. Moreover, they are very expensive: the capital cost of 1 MW pumped storage or compressed air storage is comparable to the capital cost of 1 MW wind capacity.

Redundant capacity can be installed to compensate for unexpected reductions of renewable-based electricity generation. However, these plants represent an extra cost that has to be paid somehow by consumers. In fact, such power plants that only work during peak hours—usually open cycle gas turbines—are a standard feature of most power systems. Massive introduction of wind generation, however, would require large amounts of expensive back-up peaking capacity and unless electricity prices at peak reach extremely high values there is no incentive for generators to install such plants. The inevitable consequence of insufficient back-up capacity is cutting electricity supply to customers.

Demand response offers the most convenient solution to the problem of intermittent renewable electricity generation. If consumers—or suppliers on their behalf—are able to reduce consumption during the critical moments of a sudden drop in wind generation, the supply-demand balance can be maintained and there is no need to disconnect consumers on a random basis.

Demand response can also solve another problem related to intermittent power generation. Some thermal power plants must run at a certain minimum output level (so-called minimum run or must run power plants) because otherwise they must be shut down and it takes a long time and a large amount of wasted energy to bring them back into operation. When renewable-based generation increases unexpectedly during off-peak hours (i.e., when some thermal power plants are running at minimum output level) the power system can get out of balance. In these situations demand response can work to increase load (e.g. activating devices that were disconnected like refrigerators, heat storage, etc.).

Some large industrial electricity consumers have interruptible supply contracts that allow their suppliers or the transmission system operator to cut a certain amount of energy during a certain number of hours per year, with pre-established notification periods. Usually supply is interrupted to these customers during high peaks or during unexpected generation or transmission outages. Small customers demand, however, has been considered inelastic. If AMM is introduced, small consumers will also be able to contribute to demand response.

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20 The real value of renewable generation in terms of system operation has been largely ignored or underestimated, as recently pointed out by the IEA (Grid Integration of Renewable Electricity. Trading and Transmission Roundtable: Summary and Highlights. October 2007):

> "The 'fit-and-forget' attitude to distributed generation is likely to become increasing outdated. The future will see PV taking a more active role. A number of ancillary services can be provided by PV, including: voltage control, reactive power compensation, loss compensation and harmonic filtering.
>
> At present, only limited ancillary services markets for distributed generation exist, such as revenue for reactive power in Spain. No market exists for voltage control at the distribution network level, no market for harmonic compensation, and only limited access exists for small units to balancing markets."

With AMM, small customers can react to market price increases and manage their demand accordingly. However, it is unlikely that small customers will have the time and the resources to continuously monitor electricity prices and manage their electricity demand. In a competitive market environment, it is more likely that small consumers sign flexible supply contracts foreseeing the possibility of selective demand management. By aggregating a large number of such contracts, the supplier (or a third party) will be able to actively participate in reserve markets. In fact, some companies have already been set up to specifically exploit these new possibilities: in the United States, there are more than 60 demand response service providers registered with the PJM Interconnection, about 35 registered with the New England ISO and some more in California, Texas and New York (see for instance Energy Curtailment Specialists, Inc.[21] which has thousands of customers representing over 2000 MW load under management).

1.6.3 Improving security of supply

Smart metering generates more accurate demand information and enables demand participation in energy and ancillary services markets. This means greater efficiencies in the electricity market, both as regards short-term operation (reducing wholesale market prices through demand participation) and in the long-term (reducing or delaying the need for new generation investment while keeping adequate reserve margins). More stable, less volatile wholesale electricity markets are an important contribution to improved security of supply.

Figure 4 illustrates how demand participation can reduce wholesale prices: if during peak times, demand, instead of being inelastic as today, can be reduced, the most expensive power plants, which would go into operation to satisfy peak demand, are not dispatched and the wholesale price is lower.

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21 See www.ecsny.com/index.php:

“ ECS installs an interval meter at your facility at no cost to you. This meter can help you manage your energy usage more efficiently if that is something that interests you

 A couple of times per year you would reduce power and/or run your on-site generator<

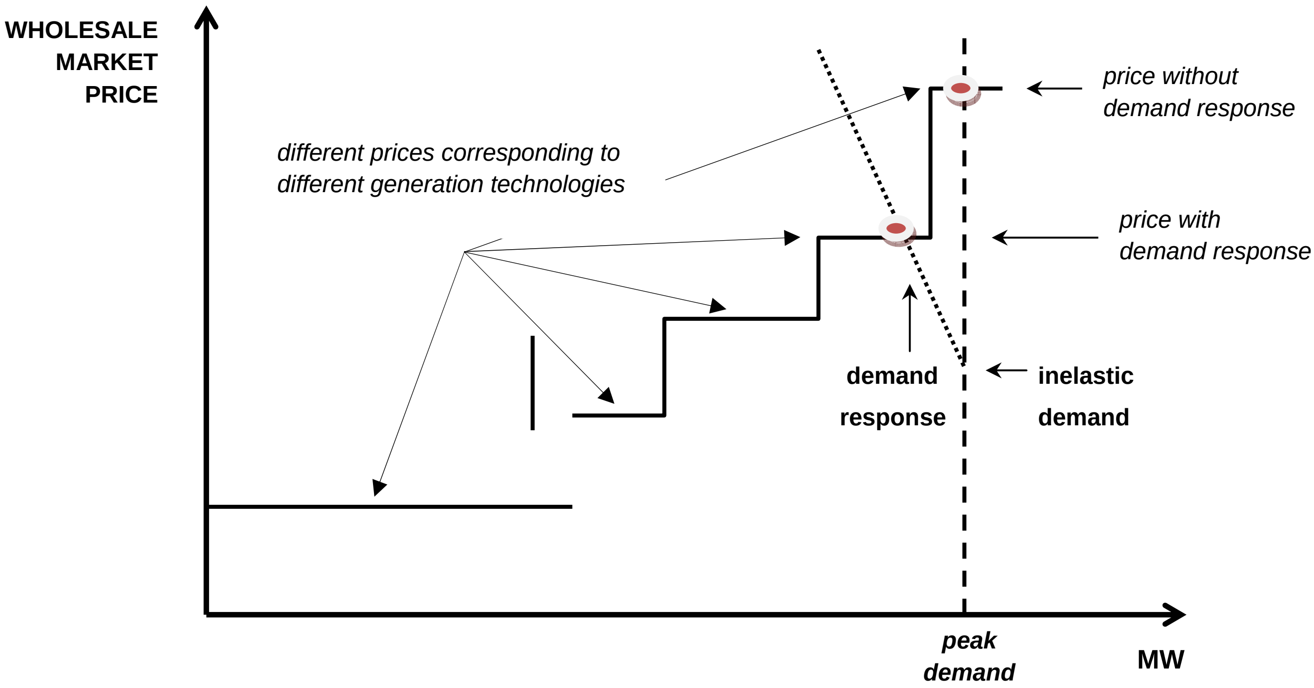
 You maintain total control over what equipment and how much power you curtail (we have no direct control over your facility)

 You will receive notice at least 20 hours before you would be called to reduce power

 There are no financial penalties for failing to curtail when requested

 You will never pay ECS a dime for participating in this program - You will only receive $$$ “

Fig. 4 Impact of demand response on wholesale market prices



Networks are generally designed to accommodate an anticipated peak load. Smart metering, when supported by appropriate demand-response mechanisms, may create the necessary incentives to modify consumption patterns sufficiently so as to reduce demand at peak times (see Figure 4 and Section 1.6.2 above), therefore reducing or delaying the need for new network investments.

As recently recognized by the North American Electric Reliability Corporation[22], demand response (DR) should be systematically included in long-term resource planning and monitoring because

> "Some DR options can have more reliability benefits than conventional supply-side peaking resources such as a combustion turbine generators ("CTG"). The reliability benefits of DR are a function of, among other things, any limits on annual interruptions, the frequency of interruptions, the duration of interruptions, the ramp-up time to reduce load, and penalties or sanctions for non-performance.
>
> Many large end-users have the necessary metering and telemetry equipment capable of providing demand response for many years. The cost of advanced metering and telemetry does not appear to be a significant barrier to increasing their participation; rather, DR design is an extremely important consideration when decisions for investments are made.
>
> Expanding DR to smaller customers can require investment in technologies to assure adequate measurement and verification of the load response, including advanced metering, load curtailment technologies, and two-way customer communications. Such investments must be recognized along-side other investments as part of overall bulk power system rejuvenation."

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22 North American Electric Reliability Corporation. "Data Collection for Demand-Side Management for Quantifying its Influence on Reliability - results and recommendations". December 2007. Available on

ftp://ftp.nerc.com/pub/sys/all_updl/docs/pubs/NERC_DSMTF_Report_012908.pdf

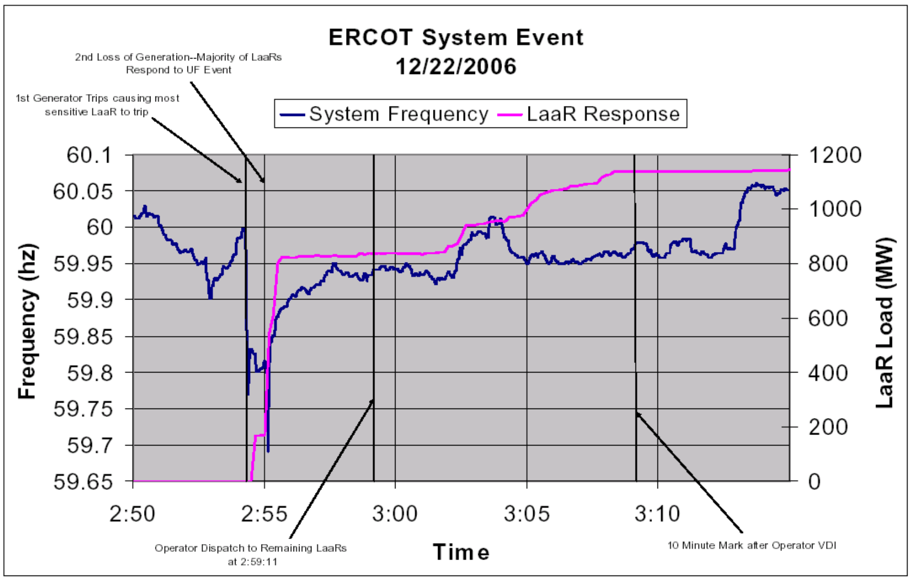
In fact, even a relatively low degree of demand response can bring substantial savings, as indicated by Northern American ISOs and RTOs[23] :

> "Research suggests that substantial gains in wholesale market efficiency can be expected from a relatively small percentage of demand response. Two factors drive the conclusion that small amounts of demand response can provide significant benefits. The first is that the supply curve is steep at high price levels, which means that a small reduction in demand can cause a large decrease in price. Second, increased use of air conditioning has resulted in the need for significant amounts of generation that is used for relatively few hours only during very hot weather. Lower demand during these few days can reduce capacity needs significantly. Based on analysis of existing supply curves and simulated case studies, demand response in the range of 5%—15% of system peak load can provide substantial benefits in reducing the need for additional resources and lowering real-time electricity prices."

However, as pointed out by the IEA, "Demand response in existing markets is typically low, since market participants lack both the incentive and the means to respond. Regulated retail prices, out-dated metering technologies, a lack of real-time price information reaching consumers, system operators focused on supply side resources and a historical legacy in which demand response was not considered important—all of these factors combine to produce the low levels of demand response seen in electricity markets today." [24]

Figure 5[25] shows how demand response helped manage a generation outage in Texas on December 22, 2006 which was triggered by the loss of an unusually large amount of generation during low-load conditions (LaaR: Load Acting as a Resource). As of October 2007, 130 LaaR providers are registered and qualified with 1,960 MW of load in the ERCOT region (Texas). It should be pointed out that these loads are controlled by traditional under frequency relays and not by modern AMM. Introduction of AMM will increase the amount and the versatility of demand response available system wide.

Fig. 5 Role of demand response on ERCOT' system event on December 22, 2006



23 Markets Committee of the ISO/RTO Council. "Harnessing the Power of Demand - how ISOs and RTOs are integrating demand response into wholesale electricity markets". October 2007. www.isorto.org/atf/cf/%7B5B4E85C6-7EAC-40A0-8DC3-003829518EBD%7D/IRC_DR_Report_101607.pdf

24 IEA. "The power to choose - demand response in liberalised electricity markets". 2003.

25 North American Electric Reliability Corporation. "Data Collection for Demand-Side Management for Quantifying its Influence on Reliability - results and recommendations". December 2007. Available on

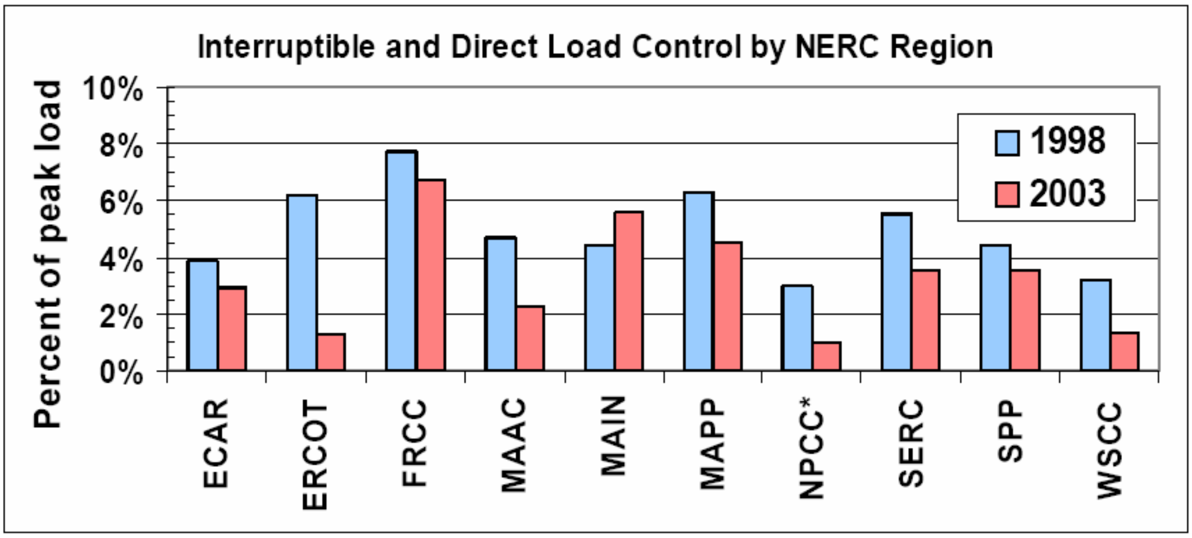
Such a significant benefit can only be achieved if the installation of smart meters is accompanied by supporting technology, new energy services and regulatory incentives, such as information displays, load aggregation, time-of-use tariffs and some form of load control to limit the amount of energy customers consume in peak times and emergencies.

This could potentially shift energy consumption away from hours or days where there is a risk of peaks in power demand. This in turn reduces the need for peak-load capacity and minimizes the overall cost of supplying power to meet demand. However, this requires a persistent, reliable demand response over time for grid planners to reflect it in the planning or development of new generation capacity.

If such benefits were in fact realised, it would offer significant savings in terms of the (deferred or) avoided costs of incremental generation capacity, thus contributing to security of supply and reduced emissions. In any case, system security is certainly enhanced by smart metering, as loads can be remotely shed if required in an emergency (e.g. network damages or temporary shortfall of production capacity). The major benefit of this is the avoided costs that would have been incurred in the event of a black-out or brown-out by enabling the controlled reduction of groups of customers in a particular area.

In the USA, existing demand response resources are estimated at 37,522 MW, corresponding to approximately 5% of the total USA electricity demand in summer 2006[26]. As shown in Figure 6[27] (see pg. 9 of reference for acronyms of the regions), the amount of interruptible and direct load control decreased in the period 1998-2003 (see FERC "Assessment of demand response & advanced metering" for detailed explanations about past and recent trends: *"the resurgence of demand response programs stems directly from their rediscovered value as a dual hedge against both reliability risks such as generation shortfalls and transmission congestion, as well as financial risks such as wholesale price spikes."*).

Fig. 6 Existing demand response in the USA (1998 and 2003) as percentage of peak load



In continental Europe (the so-called UCTE interconnected system), load management forecasts increased during recent years, as can be seen in Figure 7[28]. However, the total amount of demand

(Contd.)

ftp://ftp.nerc.com/pub/sys/all_updl/docs/pubs/NERC_DSMTF_Report_012908.pdf

26 FERC. "Assessment of demand response & advanced metering". August 2006. See www.ferc.gov/legal/staff-reports/demand-response.pdf

27 Ibidem. The acronyms correspond to different reliability areas in Northern America (USA and Canada).

28 Union for the Co-Ordination of Transmission of Electricity. "UCTE System Adequacy Forecast 2008 – 2020". January 2008. Can be downloaded from www.ucte.org/media/releases/#20080114

response (mainly interruptibility) considered in system adequacy studies is relatively low and flat, as shown in Table 2[29].

Fig. 7 Demand response forecast in the UCTE system

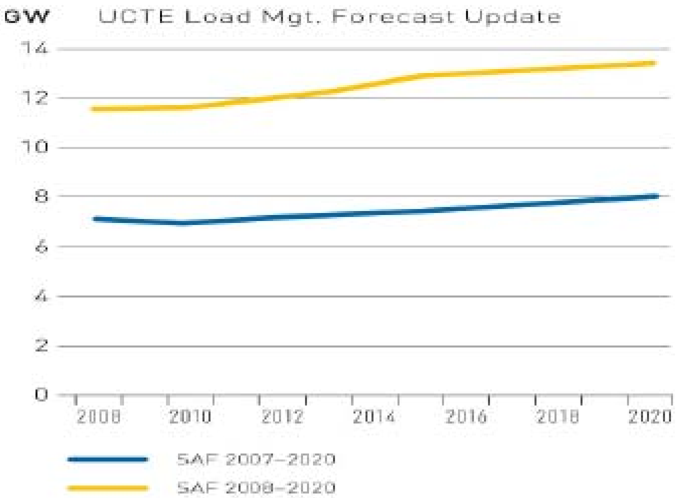


Table 2 Demand response forecast in UCTE countries

GW	2008	2010	2013	2015	2020
IT	4.00	4.00	4.00	4.00	4.00
FR	3.60	3.00	3.00	3.00	3.00
ES	2.00	2.30	2.50	2.70	3.00
NL	1.00	1.00	1.10	1.25	1.50
GR	0.40	0.60	0.80	1.00	1.30
DE	0.20	0.30	0.40	0.50	0.05
BE	0.20	0.20	0.20	0.20	0.20
HU	0.00	0.05	0.08	0.10	0.20
ME	0.03	0.03	0.05	0.05	0.05
LU	0.02	0.02	0.02	0.02	0.02
UCTE	11.45	11.50	12.15	12.82	13.32

Tab. 14 National Load Management Forecast in January 11:00 in Scenario B

Expressed as percentage of peak load (390 GW), UCTE demand response (11,450 MW) only represents 2.9 %, well below the 5% USA average and clearly below the values registered in most USA reliability areas, as can be visualized in Figure 9.

Considering now the best interconnected areas in the USA, where Independent System Operators (ISOs) and Regional Transmission Operators (RTOs) are active, the comparison with Europe (UCTE) is even worse, as shown in Figure 9[30].

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29 Ibidem.

30 Markets Committee of the ISO/RTO Council. "Harnessing the Power of Demand - how ISOs and RTOs are integrating demand response into wholesale electricity markets". October 2007. www.isorto.org/atf/cf/%7B5B4E85C6-7EAC-40A0-8DC3-003829518EBD%7D/IRC_DR_Report_101607.pdf

Fig. 8 Comparison of demand response as percentage of peak load in the USA and UCTE

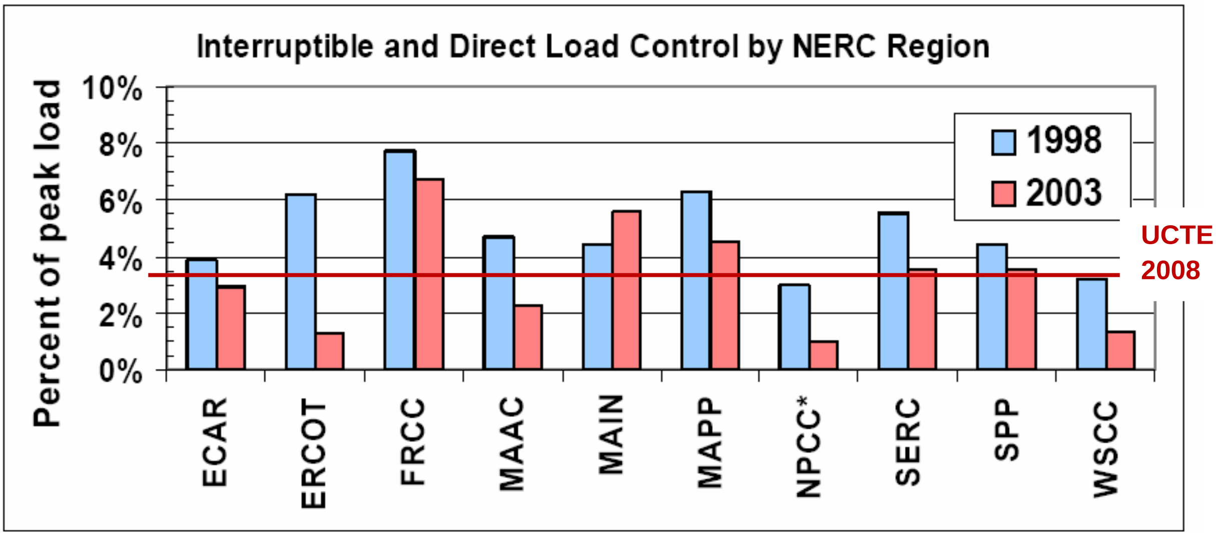

Fig. 9 Comparison of demand response as percentage of peak load in some USA areas and UCTE

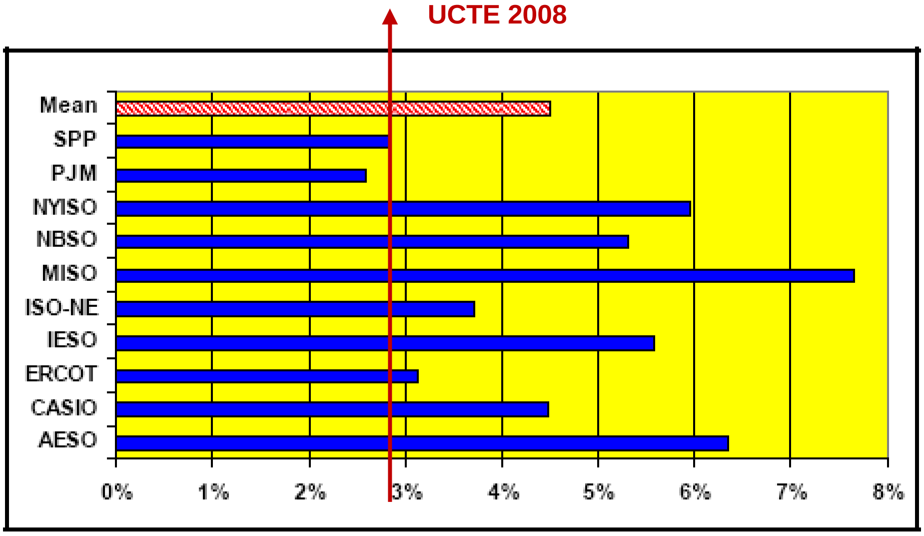

Figure ES–2: Demand response as percentage of system peak by ISO and RTO.

Many European countries even do not consider demand response in system/network planning, as indicated in the most recent UCTE System Adequacy Forecast report[31] (see box on next page).

31 Union for the Co-Ordination of Transmission of Electricity. "UCTE System Adequacy Forecast 2008 – 2020". January 2008. Can be downloaded from www.ucte.org/media/releases/#20080114

BE Belgium
Several load-shedding contacts with industrial customers are in force. The contractual capacity is about 800 MW. The estimated contribution is 200 MW, taking into account statistical availability, estimated at 25%. These contracts are part of the system services reserve.

BG Bulgaria
No DSM measures have been planned up to now.

CH Switzerland
No Load Management measures possible in Switzerland.

DE Germany
The implementation of energy saving measures and the increase in technological efficiency, respectively, will lead only to a moderate growth in electricity demand in Germany. Load Management: not relevant or no measures implemented in Germany.

ES Spain
Load forecast has been built taking into account medium and long term projections of economic growth rate (GDP) and population, as well as the impact of energy efficiency policies and Load Management: reduction of peak load growth and changes in the load duration curve.

FR France
RTE estimates that the effect of the *[Load Management]* measures taken into account in the baseline scenario will save approximately 35 TWh per year by 2020.

GR Greece
Types of Load Management measures:
- Industrial customers participate in a peak shaving scheme (new legislation since 2006).
- Irrigation rescheduling

IT Italy
Type of Load Management measure: A special customer power supply contracts for an automatic load shedding in emergency situations.

LU Luxembourg
Existing contracts with some small cogeneration units and legal issues allow us to start or to stop production during peak load. Modulation of the charging period of storage heating during the night is also possible. The value of DSM power can reach up to 5% of the national load.

ME Montenegro
Load Management is based on the bilateral contract with steal mills. It is also expected that Load Management potential can be increased if becomes necessary in next years, due to the structure of rest of the industrial consumption.

MK Former Yugoslav Republic of Macedonia
Load Management is upon the agreements with big consumers and Distribution Company. According to these agreements, they can decrease or increase their consumption, to balance the System, and ensure reliability when the system is stressed out.

NL The Netherlands
Investigations by the Ministry of Economic Affairs of the Netherlands show that there's a load management potential of 1000-1500 MW directly related to market prices. In the figures it's supposed that this capacity will grow gradually over the period until 2020. There are no specific tariffs to make this capacity available. Within the bid-system for reserve and regulation power of TenneT TSO BV part of this market potential can be used.

PL Poland
For the years 2008-2020 the load management is not considered.

PT Portugal.
In this study we did not consider any load management measures.

RO Romania
There is a regulatory frame regarding the load reduction, but in despite of this there is not any solicitation to license the consumers yet.

SI Slovenia
Increase of air-condition units in the summer and DSM is taken into consideration.

SK Slovak Republic
The energy savings can be reached mostly by controlled projects, such as DSM. The energy market may have some impact on energy savings too.

Demand response is not treated in transmission planning uniformly across EU Member States; in most cases, demand response is not directly assessed during transmission planning. This lack of harmonization concerning demand response has a negative impact on security of supply and on electricity prices in Europe.

As recognized by UCTE, “Adequacy forecast must be international as reliabilities in the different countries are linked through transmission lines and trading” [32]. Therefore, it is urgent to discuss and to harmonize how to enable, model, measure and audit demand response in EU Member States.

1.6.4 Facilitating micro-generation

Micro-generation units (e.g. small wind turbines, solar panels, micro-CHP units) allow people to generate power for their homes and small businesses. In some cases, the consumer/producer is allowed to sell the full output of the micro-generation plant to the network (or any other “public” entity with a purchase obligation), buying in the market the electricity needed to cover full demand. In other cases, where the output exceeds the amount of electricity needed by the customer at that time, only this “excess” electricity is exported onto the network[33] - i.e., micro-generation must be first consumed locally.

Micro-generation requires an export meter to measure electricity provided by the customer back to the electricity grid. Standard electromechanical meters cannot record “excess” electricity that is exported onto the network, whereas smart meters can. The introduction of smart metering provides a metering solution (but is not the only way in which) to measure the export capability of micro-generators where only “excess” electricity can be exported onto the network (“net metering”).

In the USA, net metering is mandatory (Energy Policy Act of 2005, Section 1251):

> “Each electric utility shall make available upon request net metering service to any electric consumer that the electric utility serves. For purposes of this paragraph, the term ‘net metering service’ means service to an electric consumer under which electric energy generated by that electric consumer from an eligible on-site generating facility and delivered to the local distribution facilities may be used to offset electric energy provided by the electric utility to the electric consumer during the applicable billing period.”

Smart metering gives micro-generating consumers more information about their demand—and generation—patterns, thus enabling them to better manage their local energy system.

Moreover, smart metering enables micro-generators—or energy service companies on their behalf—to “couple” several distributed micro-generation plants, thus building and managing a (larger) virtual power plant.

1.6.5 Increasing transparency

Smart metering provides a large amount of useful information. This information enables consumers to change their behavior, suppliers to market new services and network operators to improve network and system operation. Furthermore, smart metering enables demand to participate in energy markets, thus improving their efficiency, contributing to less volatile prices and improved security of supply.

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32 Ibidem.

33 The Irish regulator (CER) decided in 2007 that micro-generators should be appropriately rewarded for any electricity exported to the system; that smart metering offers the best option for metering micro-generation; and that micro-generation would be included as a priority group in the forthcoming smart metering programme. See “Arrangements for Micro Generation – Decision and Response to Comments Received”, (CER/07/208)

www.cer.ie/en/electricity-distribution-network-current-consultations.aspx?article=5b5a122e-5182-42a2-852c-00e71bc7c949

Increased transparency is an important benefit for all market participants and also for regulators who will be able to better monitor energy markets and to introduce more efficient incentives.

In the information and knowledge society, availability and dissemination of information is crucial for the development of new products and services, as well as for productivity gains. Although some benefits resulting from smart metering are easily identified and can be, in some cases, easily quantified, as presented in the above paragraph and in the previous sections of this paper, others are not so easily anticipated. For instance, manufacturers of electrical household appliances will inevitably adapt their strategies to smart metering, introducing into their appliances (refrigerators, dishwashers, etc.) more sophisticated control devices that can communicate with consumers (and suppliers) through smart meters. This evolution of household appliances will have a very important long-term impact on electricity consumption levels and patterns, although it is not easy to predict today how fast this transformation will take place.

2. Metering regulatory frameworks in the European Union

2.1 Regulated versus liberalized metering market model

There are two main types of electricity metering regimes in the EU:

- the regulated market, where designated companies operate metering activities within a regulated framework;
- the liberalized market, where the meter service is open to competition.

Table 3 indicates the metering regime in each EU Member State[34].

With the exception of Germany, the Netherlands and the UK, currently all other countries have a regulated market regime. In most regulated cases, metering is not separated from other activities (either from distribution or supply). However, a small number of countries have introduced some level of metering unbundling (e.g. separate accounts). For example, in Italy accounting separation has been in place since 2001. Following a reform in 2007, functional unbundling for vertically integrated utilities in Italy is required from 2010.

In two liberalized markets (UK and NL) the current uncertainty about the future organisation of the meter market blocks the implementation of smart metering infrastructure (see Chapter 3 below). It is expected that the metering regime in the Netherlands will undergo radical changes, reverting back to a regulated regime by 2009.

The business case for investing in smart meters differs depending on the type of regulatory model in place.

In the regulated market (which prevails in Europe) the metering service is a monopoly business carried out by grid operators and therefore paid by the final customer either by regulated metering tariffs (set by the regulator) or as part of grid tariffs. By allowing for higher meter tariffs for smart meters, regulatory incentives can be given for the installation of smart meters, or there could be an obligatory roll-out. However, until now this possibility has been pursued only in two countries (Italy and Sweden[35]).

Where the meter market is open to competition, the consumer or the supplier decides on the type of meter to be installed. Metering services are carried out by an unregulated third party. It is therefore necessary to provide for a certain level of standardisation and interoperability of the meters installed in

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34 For Belgium the situation differs according to the three regions – Brussels capital, Wallonia and Flanders.

35 In Sweden this was indirectly introduced by a law which requires monthly meter reads by 1 July 2009.

order to avoid technical barriers to customer switching. In liberalized markets, it is the supplier who bears the cost of the smart meter, and thus the business case he faces is different to that of a distribution network operator who in a regulated market would reap the rewards of system wide potential benefits, and (in most cases) be reimbursed for the investment through allowed regulated revenue.

Table 3 Regulatory regime of electricity meters

	LIBERALIZED	REGULATED UNBUNDLED	REGULATED BUNDLED	OTHER
Austria			X	
Belgium		X (2)		X (1)
Bulgaria				
Cyprus			X	
Czech Republic		X		
Denmark			X	
Estonia			X	
Finland			X	
France				X
Germany	X			
Greece			X	
Hungary			X	
Ireland			X	
Italy			X	
Latvia			X	
Lithuania			X	
Luxembourg				X
Malta			X	
Netherlands	X			
Poland			X	
Portugal		X		
Romania				
Slovakia			X	
Slovenia			X	
Spain				X
Sweden			X	
United Kingdom	X			

2.2 Ownership of electricity meters

In most countries, ownership of the customer meter lies with the distribution network operator. However, different possibilities exist depending on the country. For example, in the UK it could be owned by the distribution network operator, the supplier, the metering company or the consumer. Different potential owners of meters may curb investment in smart meters, for example if the meter belongs to the customer, they may be unwilling to upgrade the existing meter. Ownership of the meter is also an important factor which comes into play when there is an absence of standards governing the interoperability of metering systems, particularly in liberalized markets. In the Netherlands or the UK (which are currently liberalized) smart meters are also owned by the supplier. The supplier faces a potential stranded asset risk if he invests in a smart meter and the customer subsequently changes supplier. This underlines the need for a scheme whereby customer are able to retain their meters if they change supplier, and for the urgent need for any installations to comply with interoperability standards.

Table 4 indicates meter ownership in each EU Member State.

Table 4 Ownership of electricity meters

	CONSUMER	DISTRIBUTOR	METERING COMPANY	SUPPLIER	OTHER
Austria					
Belgium		X			X
Bulgaria					
Cyprus					X
Czech Republic					
Denmark					X
Estonia		X			
Finland					
France					X
Germany		X	X		
Greece					X
Hungary					
Ireland		X			
Italy		X			
Latvia		X			
Lithuania		X			
Luxembourg		X			
Malta		X			
Netherlands		X		X	
Poland	X	X			
Portugal		X			
Romania	X	X	X	X	
Slovakia		X			
Slovenia	X				
Spain	X	X		X	
Sweden		X			
United Kingdom	X	X	X	X	

2.3 Party responsible for smart meter operation

Meter operation includes four distinct activities:

- Installation (I)
- Maintenance (M)
- Reading (R)
- Data Management (DM).

As shown in Table 5, generally it is the distribution network operator who is responsible for operating meters and smart meters. In some countries, it is another party who is responsible for some of the above mentioned activities.

Table 5 Party responsible for meter operation

	CONSUMER	DISTRIBUTOR	METERING COMPANY	SUPPLIER	OTHER
Austria		I,M,R,DM			
Belgium		I,M,R,DM			I,M,R,DM
Bulgaria					
Cyprus					I,M,R,DM
Czech Republic					
Denmark		R			I,M,DM
Estonia		I,M,R,DM			
Finland	I,M	I,M,R,DM			
France	I	I,M,R,DM		DM	
Germany		I,M,R,DM	I,M		
Greece		R,DM			I,M
Hungary					
Ireland		I,M,R,DM			
Italy		I,M,R,DM			
Latvia		I,M,R,DM			
Lithuania		I,M,R,DM			
Luxembourg		I,M,R,DM			
Malta		I,M,R,DM			
Netherlands		I,M,R,DM	I,M,R,DM	DM	
Poland	I,M	I,M,R,DM			
Portugal		I,M,R,DM			
Romania	I	I,M,R,DM	I,M,R,DM	I	
Slovakia					
Slovenia		I,M,R,DM			
Spain	M	I,M,R,DM			
Sweden		I,M			
United Kingdom	I,M			I,M,R,DM	

2.4 Frequency of measurements and meter reading

One case for smart metering is that it dispenses with the high (labour related) costs of manual meter reads. The frequency of meter reads differs from country to country.

In most EU Member States, meters of small, low-voltage customers are read once a year. In Austria a licence obligation requires a meter read every three years (but in practice it is normally once per year). Only few countries have several meter readings a year: in Spain it is six times per year, in Ireland it is four times per year, in France and Portugal it is twice per year for low-voltage customers. In Sweden the government has mandated monthly invoicing from July 2009 which has encouraged widespread deployment of smart meters.

Large customers consumption (usually also including peak load) is measured on an hourly basis or less (see Table 6[36]). These (legacy) metering periods depend on technical considerations related to generation and system operation; they are not motivated by consumer considerations.

36 EURELECTRIC. Report on customer switching in Europe. March 2003.

Table 6 Metering periods in some EU Member States

Country	Metering Period
Cyprus	20 minutes
Czech Republic	Usually hourly; in some cases 15 minutes.
Denmark	Hourly
Finland	Hourly
France	10 minutes
Germany	15 minutes
Hungary	Variable; half-hourly for large customers
Ireland	15 minutes
Netherlands	15 minutes
Norway	Hourly
Poland	Hourly
Portugal	15 minutes
Spain	Hourly
Sweden	Hourly
United Kingdom	Half hourly

The remaining customers who do not have hourly metering are billed according to pre-defined load profiles: "The limit for load profiling is quite different from country to country and ranges from customers using 60 MWh to 400 MWh or from 5 to 150 kW"[37].

3. Smart meter policies in the European Union

3.1 Status of smart metering public policies in place or planned

Although only very few EU countries have electricity smart metering policies currently in place, experiences are being reviewed and public policies are under consideration in many EU Member States (including Malta which has a derogation from opening up the electricity market). Italy and Sweden have taken a lead role with others now following.

Table 7 indicates the situation of electricity smart metering public policies in EU Member States, ranging from policies mandating full introduction of smart meters to no policies yet.

Four Member States have already decided full mandatory introduction of smart meters:

- In **Italy**, following a voluntary meter replacement programme launched by the incumbent utility ENEL (with regulatory approval) in the 1990s, the regulatory authority (AEEG) has mandated full introduction of smart meters according to established minimum functional requirements in 2006. Replacement shall be completed by December 2011. Italy is a frontrunner in terms of smart meter installations with 86% of low-voltage customers already equipped with smart meters.
- In 2003 **Sweden** became the first EU country to mandate smart metering (indirectly) by legislating new national metering regulations requiring all residential customers to be read monthly by July 2009.
- In March 2007 the governments of **Spain** and **Portugal** decided on the introduction of harmonized smart meters for all customers as a means to improve the functioning of the Iberian Electricity Market. Spain has already adopted legislation mandating full meter replacement by December 2018; Portugal has not yet adopted new legislation but the regulatory authority (ERSE) proposed that replacement should be concluded by December 2015. In Portugal, all

37 Ibidem

medium, high and very-high voltage customers are equipped with AMR since 2005, following a previous decision by the regulatory authority.

In other countries there have been political statements proposing full roll-out within a specified number of years (e.g. within 5 years in Ireland according to the 2007 Agreed Programme for Government, and 10 years in the UK according to the 2007 Energy White Paper).

Several EU countries are at (or have just completed) public consultation stage. In Austria and Ireland, where the regulatory authorities are in principle in favour of introducing smart meters for all customers, the regulators have completed public consultations in 2007, and each are now engaged in follow up projects.

Table 7 Smart metering public policies

	FULL COMPULSARY INTRODUCTION	PARTIAL COMPULSARY INTRODUCTION	UNDER DISCUSSION	NO POLICY
Austria			X	
Belgium				X
Bulgaria				
Cyprus				X
Czech Republic				X
Denmark				X
Estonia		X		
Finland				X
France				X
Germany				X
Greece				X
Hungary			X	
Ireland			X	
Italy	X (2011)			
Latvia			X	
Lithuania				X
Luxembourg				X
Malta			X	
Netherlands			X	
Poland				X
Portugal	X (2015?)			
Romania				X
Slovakia				X
Slovenia				X
Spain	X (2018)			
Sweden	X (2009)			
United Kingdom			X	

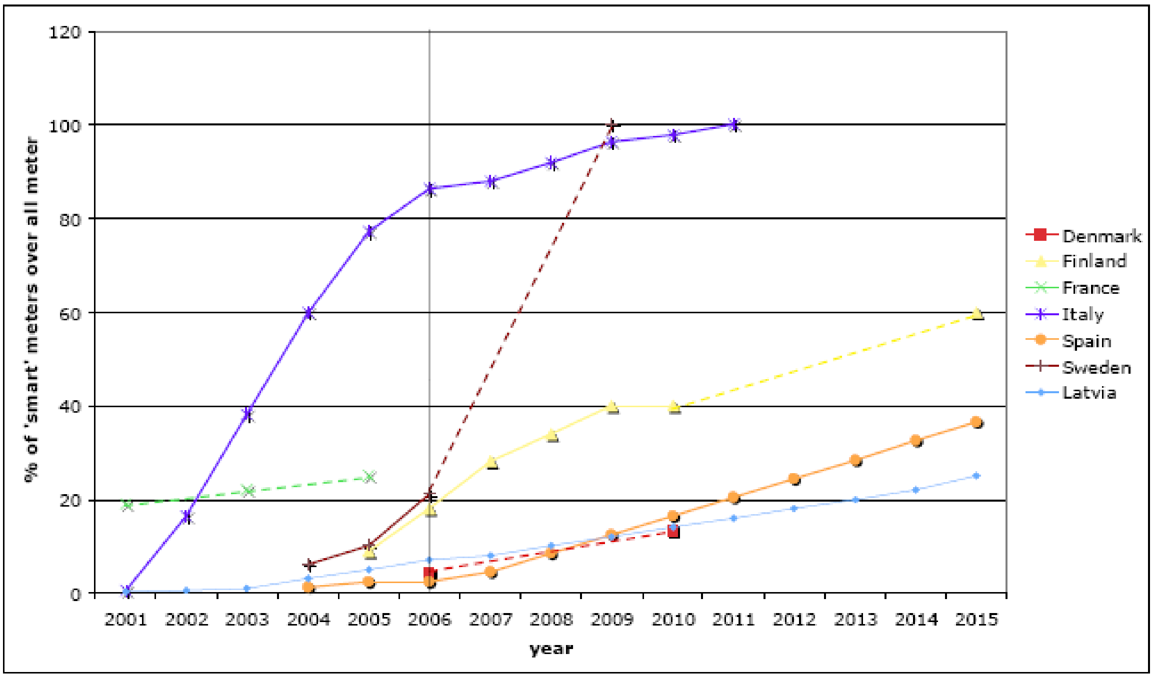
Many countries have pilot projects ongoing including Austria, Czech Republic, Denmark, Finland, Greece and UK while others are about to initiate pilot projects:

- Cyprus—10,000 customers in 2008-2009.
- Ireland—25,000 customers starting in 2009—the outcome will inform the public policy to be put in place for a full roll-out.
- France—300,000 residential customers by 2010.

Since 2007 large-scale deployments of Automated Meter Management (AMM) have been announced in Austria (LINZ STROM), in France (ERD), in Germany (Yello and RWE), in Italy (Enel, ACEA, AEM-Torino and ASM Brescia), in the Netherlands (Oxxio and Nuon) and in Spain (Endesa and Enel Viesgo). However, the current experience with a full rollout of smart meters at low-voltage (household and non-household) level remains limited in Europe.

Figure 10 [38] indicates existing and planned penetration rates of smart meters in seven EU Member States.

Fig. 10 Smart meter penetration rate in selected EU Member States



In the next pages national smart metering policies are briefly described.

In **Sweden**, a law was passed in 2003 requiring mandatory hourly metering (from July 2006) for final customers with a fuse subscription of 63 A. From July 2009 all metering points should be read monthly and final customers should be invoiced based on their real consumption. Although the law does not prescribe as to how this should be done, in practice all households in Sweden will have smart meters as of 1 July 2009.

The distribution network operators, who are responsible for meter reading, bear the cost of meter replacement. However, for some distribution network operators the costs/benefits balance because of the high cost of manual meter reads in low populated rural areas. Different meter models and technologies are being deployed.

Winter trials[40] were conducted on a pilot basis during the winters of 2003 and 2004 to test demand response to peak hours. They showed that hourly metering reading, combined with appropriate tariff structures, can increase the price sensitivity of customers.

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38 ERGEG. "Smart metering with a focus on electricity regulation". October 2007. See www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/CEER_ERGEG_PAPERS/2007/Positions/E07-RMF-04-03_SmartMetering_final.pdf

40 The Market Design Research Programme (www.marketdesign.se)

As all four national electricity markets in the Nordic region are fully liberalized and have similar organizational structures, arguably smart metering developments in Sweden has prompted progress elsewhere with Denmark, Finland and Norway each planning to reach significant percentages of smart meter penetration: according to the 2007 ERGEG report these figures are 13% in 2010 for Denmark and 60% in 2015 for Finland; and possibly 100% rollout in Norway by 2013.

In **Finland** customers that participate in the competitive electricity market or who make a new network contract and whose premises are equipped with main fuses of over 3x63 A must have hourly metering in principle:

> "According to the Electricity Market Act, consumption places that are equipped with main fuses of over 3 x 63 amperes must have metering based on hourly metering. However, if an electricity user does not want, the hourly metering is not required for those consumption places to which electricity is bought with terms and conditions applying to retailer's obligation to supply, if a service (connection) contract applied to a consumption place has been agreed before the 1st of January 2005 or if consumption in a consumption place is no more than 5,000 kWh per year**."** [41]

There have been full-scale installations on a voluntary basis by a number of companies (Vattenfal, Fortum, Vantaa Energy).

In **Denmark**, since January 2005, there is mandatory hourly metering for final customers with consumption over 100 MWh per year. AMR has been installed on a voluntary basis, and currently there is a discussion about mandatory installation of AMR for all customers (see box on next page).

41 Energy Market Authority, Finland. Annual Report to the European Commission. See www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/NATIONAL_REPORTS/NR_2007/NR_En/E07_NR_Finland_EN.pdf

Meter reading

Today distribution network companies have a natural monopoly on gathering customer data from meter reading. The net companies charge a price which according to legislation must be cost reflective and which can be accommodated within the income cap fixed by DERA.

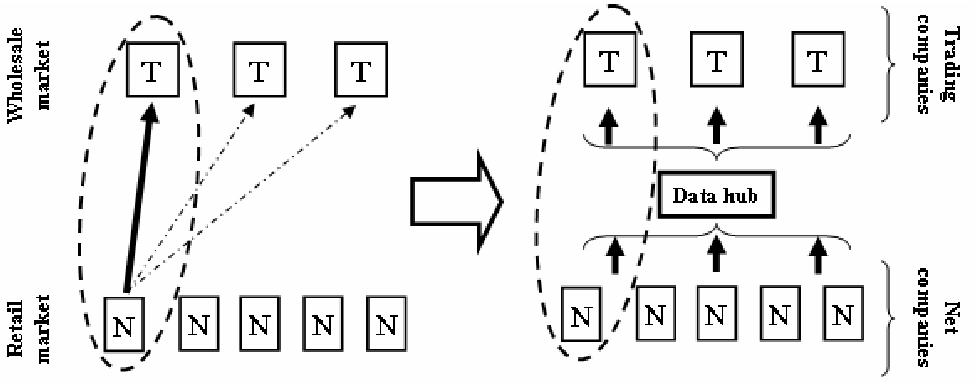
After collecting the data, the net companies are required to share the data in a non-discriminative manner with both each other and the trading companies on the wholesale market.

DERA since the start of liberalization has detected problems with the timely communication of required data. The situation has improved, but reflections on alternative data communication models have been made. Especially the option of establishing some kind of joint data-hub is now being elaborated on.

Many supply companies are owned by company groups also consisting of distribution network companies, which might give incentives to discrimination between "own" supply companies and newcomers entering the market.

Though the problem is addressed in the monitoring of unbundling expressed by the mandatory compliance programmes this constellation might still be a problem on the retail market, yet very difficult for the competition authority or energy regulator to prove.

Figure 2—Vertical ownership may distort incentive to share information in a non-discriminative manner



The thin dotted line illustrates the distorted incentive to share customer information with competitors.

Another issue regarding meter reading is whether or not a demand about a new metering device with the possibility of online reading ("smart metering") should be set forth by the regulator.

There is no doubt that online reading will benefit the functionality of the market since data regarding consumption may be supplied every minute (in theory) hence providing network companies with a good possibility to forecast demand. Today the net companies only receive one meter reading a year from the majority of customers not subject to hourly metering.

In a report made by the Danish Energy Agency these short- and long-run gains and losses are evaluated. The report concludes that, at present, the cost of implementing online readers exceed the gains for households. However, the report also stress that due to the fact that the unit price of online meters has fallen, and are expected continue to fall, there is a good probability that the gains from implementation will be able to finance the investment. In addition smart metering devices could be used for a number of other purposes than just reading energy consumption.

From a network company's point of view there might be significant benefits from implementing online readers. Today these benefits have already caused some network companies to find it to be a paying proposition to implement online meters, despite that the cost is purely self financed. As the price of online meters is decreasing more net companies are expected to follow this road.

End 2006 on-line meter reading was established for 42,900 customers with compulsory hourly meter reading (above 100,000 kWh customers) and for 136,900 other customers. The yearly consumption of these total of around 180,000 customers was 18 TWh (53 % of consumption). Plans for 2007 indicate that 140,000 additional "smart meters" will be installed.

Source: Danish Energy Regulatory Authority (DERA). 2007 National Report to the European Commission. http://www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/NATIONAL_REPORTS/NR_2007/NR_En/E07_NR_Denmark-EN.doc

In **Norway**, since January 2005, there is mandatory hourly metering for final customers with consumption over 100 MWh per year. About 10 distribution network operators have installed AMR on a voluntary basis, and currently there is political discussion (but no formal decision yet) about mandatory installation of AMR.

In June 2007 the regulator (NVE) indicated a possible rollout to all customers by 2013[42], but this will be further assessed during the course of 2008. The Norwegian electricity industry association (EBL) is working on voluntarily functional requirements. The regulator (NVE), in co-operation with industry and stakeholders, is developing functional requirements for smart meters which are expected to be established in 2008 and enter into force by 2009. Investments by distribution network operators in smart metering should be financed within their existing income regimes. No new incentives are considered necessary by the regulator.

Smart metering is indeed a powerful tool to promote integration of regional markets, as can be seen not only from the Nordic market example (see box below), but also from the Iberian market (see next paragraph).

Nordic AMR Forum (Automatic Meter Reading)
Background

The Nordic electricity wholesale market is one of the first international electricity markets in the world. Until the recent time the integration did not directly involve retail markets, which remained national. The Akureyri declaration of the Nordic energy Ministers pointed out in 2004 a further development and deeper integration of the national electricity markets as an important strategic target. Furthermore, a truly common Nordic retail market with free choice of supplier was set as a strategic objective to the Forum of Nordic Regulators (NordReg) in 2005.

A study conducted in 2005 by VTT and SINTEF Energy Research for NordReg has uncovered and mapped several differences, related to collection and handling of metered data among Nordic countries, both when it comes to technical and regulatory issues. These may create critical barriers for establishment of a common Nordic end-user market and thus have to be resolved. The Nordic Energy Regulators group's (NordREG) report "The Integrated Nordic End-User Electricity Market" identifies establishment of a Nordic AMR Forum as an important part in creation of a common Nordic power market.

Project goal

The main long-term objective of the proposed action is to encourage a cost-efficient implementation of AMR solutions in the Nordic countries in order to establish a more flexible and well-functioning electricity market. In order to achieve this, the project will establish a common Nordic AMR Forum. The AMR Forum will pursue the following additional objectives:

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

Source: http://www.nordicenergy.net/section.cfm?id=3-0&path=4,35

In November 2006 the governments of **Spain** and **Portugal** agreed on the need to ensure full regulatory compatibility between the two electricity markets in order to enable the functioning of a truly integrated Iberian Electricity Market. In March 2007 a work plan was approved by the two governments, including provisions for full compulsory introduction of smart meters. The regulatory authorities were requested to submit to the two governments, by October 2007, a joint document describing minimum required functionalities of smart meters for household customers and proposing a

42 www.nve.no/FileArchive/185/Englesk%20notat.doc

44 This joint document was never produced.

rollout timetable aimed at facilitating customer switching within the Iberian retail market[44]. The governments also indicated that from July 2007 all new installed meters shall be electronic with remote metering capabilities[45].

In August 2007 the Spanish government approved a law[46] defining electricity metering conditions. Different meter functionalities are established according to the customer's contracted power. A rollout timetable was published in December 2007[47] that foresees the replacement of all meters before December 31, 2018.

In December 2007, following public consultation, the Portuguese regulatory authority (ERSE) published its proposal to the Portuguese government[48], suggesting a pilot project followed by rollout between 2010 and 2015. A final decision by the Portuguese government is not yet known. In Portugal, since 2005, as a result of a previous decision by the regulatory authority (ERSE), all customers and generators connected at medium, high and very-high voltage levels have AMR; their meters are integrated into a single national data management structure.

In a joint discussion document on harmonization of customer switching procedures published in February 2008[49] the two regulatory authorities (CNE and ERSE) mention the need of metering harmonization. It is not clear, at the present stage, what kind of metering harmonization, if any, will be implemented in the two countries.

In the **United Kingdom**, the Ministry (BERR) conducted a consultation in 2007 on the governments' proposals for smart meters (which would apply to both electricity and gas use) included in its Energy White Paper[50]. The proposals foresee rolling-out over 5 years (from 2008) for business and 10 years for domestic consumers. For smaller businesses and households, BERR intends to undertake a more detailed economic analysis of the costs and benefits of smart metering in parallel to its consultation. The rationale for the business sector draws from the UK's experience with the Carbon Trust Advanced Metering Field Trials[51].

The most controversial issue is the treatment of households and small business. A critical debate in the UK is whether to stick with the competition model (in place since 2003) or go for a regional franchise approach (whereby meter installers would bid to fit all the meters in an area, irrespective of the energy supplier). The latter is the option favoured by the Energy Retail Association (ERA), while the regulatory authority (Ofgem) rejects mandating the installation of smart meters in concluding that competition, rather than regulation, is the best way to deliver (an estimated 45 million) smart meters.

A decision from the UK government is expected by April 2008 (see box on next page). Following an earlier public consultation by the regulator in 2006 on "Domestic Metering Innovation 2006", two key initiatives are underway in the UK;

A 2-year pilot project under the Energy Demand Research Project that the government is co-funding (up to 10 million pounds) with suppliers, which examines smart metering and consumer behaviour.

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45 www.erse.pt/NR/rdonlyres/D6257911-FA51-4D7F-B78D-E0FDB69AAB13/0/Telecontagem_Doc_Consulta_Publica_versaointegrada.pdf

46 REAL DECRETO 1110/2007, de 24 de agosto. See www.cne.es/cne/doc/legislacion/RD1110_2007.pdf

47 Orden ITC/3860/2007. See www.boe.es/boe/dias/2007/12/29/pdfs/A53781-53805.pdf

48 www.erse.pt/vpt/entrada/consultapublica/detalhe/?id=115

49 www.cne.es/cne/doc/mercados/Proc_Cambio_Comercializador.pdf

50 Energy White Paper; Meeting the Energy Challenge (www.dti.gov.uk/energy/whitepaper/page 39534.html) sets out a range of measures by the government to change consumer behaviour, following an earlier consultation by the Ministry in 2006 on Energy Billing and Metering: Changing Customer Behaviour – An Energy Review Consultation (www.dtie.gov.uk/file35042.pdf)

51 These tested the use of smart meters in the business sector, starting in 2004. See www.carbontrust.co.uk/publications.

Efforts by the Energy Retail Association (made up of the 6 biggest suppliers of domestic customers), under the supervision of the regulator, to voluntarily agree minimum standards that can be applied to all smart meters. This work should increase interoperability and reduce the potential for stranded assets (when a supplier in a liberalized market installs a smart meter, and the customer subsequently changes supplier).

Smart Metering

The Government is committed to seeking measures to achieve carbon savings of 0.2 MtC by 2010 through better metering and billing. It believes that one way this could be achieved is if all new and replacement meters are 'smart'.

Smart meters allow energy suppliers to communicate directly with their customers, removing the need for meter readings and ensuring entirely accurate bills with no estimates. They tell people about their energy use through either linked display units or other ways, such as through the internet or television. They could offer gas and electricity customers:

- more accurate - and fewer - estimated bills;
- information that could help them use less energy and encourage energy efficiency;
- lower costs through reduced peak consumption, because this would reduce the need for new network investment;
- increased security of supply. because the less energy we use, the less we need;
- more sustainable consumption through reduced carbon emissions.

BERR is co-funding with supplier-led consortia a series of two-year trials which will test consumers' responses to different interventions, including combinations of some or all of the following:

- smart meters;
- clip-on real time display units (these work off existing energy meters to give the consumer instant readings of energy and other information, such as the cost of energy, by way of a display device in the home);
- improved billing (with and without smart meters);
- energy efficiency information;
- community engagement.

The trials, which began in July 2007, and which are being managed by Ofgem, will involve around 40,000 households across Great Britain.

Also in August 2007, BERR published its second consultation on energy billing and metering seeking views on a range of measures which were set out in the 2007 Energy White Paper. The measures, which aim to heighten awareness of energy use and reduce consumption, are to require:

the provision of comparative historical consumption data on bills for all domestic gas and electricity customers;
electricity suppliers to provide (where technically possible) a real-time display unit when a meter is replaced or newly installed in domestic premises;
electricity suppliers to provide a real-time display to all consumers who request one until 2010; and
gas and electricity suppliers to install smart meters in those parts of the SME sector, above a certain usage threshold, where it is cost-effective to do so.

Views were invited on the Government's expectation that, over the next ten years, all gas and electricity customers will be given smart meters with visual displays. The Government intends to respond to the consultation in Spring 2008.

Source: http://www.berr.gov.uk/energy/environment/smart-metering/index.html

In **Ireland**, the regulatory authority (CER) welcomed the support by respondents to the consultation for a mandatory rollout of smart meters[52], and determined that micro-generators would be included as a priority group in the smart metering installation plan[53]. The CER has decided that micro-generators will have the option to have an interval meter installed until such time as smart metering is available (free) under the smart metering project rollout—for the first 100 micro-generators who

52 An information paper by the regulator "Smart metering – the next steps in implementation (CER/07/198), 15 November 2007, on www.cer.ie, proposes a framework in which the future scope of smart metering can be established.

53 "Arrangements for MicroGeneration – Decision and Response to Comments Received" (CER/07/208), 20 November 2007, on www.cer.ie.

request an interval meter, only the installation cost and not the actual cost of the interval meter will be charged.

The regulator is working with the Ministry, the distribution network operator, suppliers and stakeholders on Phase 1 of the implementation of the rollout. This involves setting up and running a smart metering pilot and completing other preparation work to structure and implement an optimally designed smart metering programme that will embrace all elements of smart metering relevant to the Irish electricity market (e.g. the possible introduction of time of day pricing, exploring demand response). As increased functionalities tend to increase costs, a first step is to identify the scope of functionality and the speed with which a smart metering programme can be deployed, taking cognizance of the systems with which smart metering must integrate.

A pilot project involving the installation of smart meters in 25,000 customers will start in 2009. No policy decision will be made on the full rollout of smart meters, prior to the completion of the smart metering pilot scheme and the completion of a cost-benefit study. If smart metering rollout goes ahead, the distribution network operator would incur the costs which would be recovered through the network charges approved by the regulator.

The Republic of Ireland will also look to the experience in **Northern Ireland** which has a long experience with prepayment meters. Northern Ireland is also planning a small-scale smart metering pilot programme in 2008 (potentially 6 pilots of about 200 customers each, over a 12 month duration).

Energy efficiency is driving a major metering market reform in the **Netherlands**. In summer 2008, the Netherlands is expected to adopt legislation which will restructure the metering market (from liberalized to regulated) and will result in full nationwide smart metering deployment (to over 7 million household and small businesses) by 2014.

In **Austria** the regulatory authority (E-Control) launched a public consultation in 2007 and is now analyzing several options. It is expected to have a final decision by the end of 2008. In their view [54]

> "In contrast to Italy, the Netherlands and Sweden, which plan the nationwide introduction of innovative metering systems in their electricity sectors over the next five years, in Austria there are no strong arguments such as high electricity prices, demand or non-technical system losses, to justify such a step. Nevertheless, E-Control would welcome the introduction of smart metering systems for domestic and small business electricity consumers because it would stimulate competition, enhance supply security and have a positive impact on planned energy efficiency programmes.
>
> On the Austrian electricity and gas markets metering services are normally the responsibility of the system operators. They are compensated for the costs incurred in connection with meter installation, operation and reading by the regulated charges for metering services. In the light of information on projects abroad, E-Control believes that investment in innovative metering systems would be economically viable for electricity system operators in Austria at the current maximum rates for metering charges. This expectation has been borne out by the projects already under way in the country.
>
> However, in order to ensure that there are overall benefits for all market participants E-Control plans a cost-benefit analysis of the introduction of advanced metering systems in Austria."

Three distribution network operators in Austria have voluntarily initiated pilot projects:

- One (500,000 customers) intends to roll out 10,000 smart meters in 2008 and to all customers within 7 years (by 2015)

54 E-Control. Market report 2007 – national report to the European Commission. www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/NATIONAL_REPORTS/NR_2007/NR_En/E07_NR_Austria-EN.pdf

- One (250,000 customers) intends to rollout 20,000 smart meters in 2008, and to all customers within 12 years.
- One (20,000 customers) has already 3000 smart meter installed.

In **Estonia** AMR is already mandatory for all customers above 63A. A company-driven initiative of the distribution network operator should increase the number of installations from the current 8% level to 41% (or 260,000 customers) by 2010.

The **Hungarian** regulator (HEO) will consult industry in 2008 on the pros and cons of smart metering and will review international practices.

In **Cyprus**, the potential of smart metering is under study. Automatic Meter Reading (AMR) has been introduced by the Electricity Authority of Cyprus (EAC) and is applicable to consumers supplied at medium-voltage level. Smart metering has not yet been implemented. However, in 2008-2009 a company-led pilot project involving over 10,000 meters will be undertaken in order to estimate the full benefits of smart meters, with possible gradual roll out to all customers from between 2009 (2.5% planned installations) and 2014 (100% or approximately 77,000).

In **Romania** “The full opening of the electricity market requires hourly meters for the customers, wide internet access and the introduction of standard consumption profiles. It also involved the review of the rules to switching the supplier in order to meet the household customers’ specific needs.” [55]

In **Belgium**, the Flemish Region is analyzing a new “market model” including the possibility of introducing smart meters.

In **Germany**, installation, operation and maintenance of electricity meters was liberalized. However, there is no policy on smart meters and minimum requirements regarding data are not harmonized; network operators are obliged to publish minimum requirements but not all of them have done it so far and the regulatory authority (BNetzA) is considering the adoption of regulatory measures to improve the current situation [56].

Yello Strom, a gas and electricity retail supplier with about 1.4 million customers will bring web-based smart meters nation-wide to the German market in summer 2008[57]. This is a cooperation project with Microsoft[58].

RWE will start in summer 2008 a pilot project rolling out smart electricity meters to 100,000 households in Mülheim an der Ruhr. RWE’s aim is to develop a smart meter with an “open standard” which can function with all common billing programs and also integrate gas and water meters.[59].

Other EU Member States are currently reviewing developments on metering costs and studying different approaches to the rollout of meters.

3.2 EU legislative initiatives related to smart metering

Two existing EU Directives directly relate to metering:

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55 The Romanian Energy Regulatory Authority (ANRE). Annual report to the European Commission. www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/NATIONAL_REPORTS/NR_2007/NR_En/E07_NR_Romania-EN.pdf

56 www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/NATIONAL_REPORTS/NR_2007/NR_nl/E07_NR_Germany-LL_v2_0.pdf

57 https://www.yellostrom.de/presse/index.html

58 www.microsoft.com/germany/presseservice/detail.mspx?id=532111

59 www.rwe.com/generator.aspx/rwe-energy/pressemitteilungen/2008/02-19/language=de/id=611820/rwe-energy-flaechendeckender-einsatz-intelligente-zaehlern.html

- Firstly, the Metering Directive[60] (adopted in 2004) has streamlined regulations so that electric, gas and water meters approved in one Member State are automatically approved for use in all other Member States. The objective of this Directive is to make it easier for EU meter manufacturers to market their products throughout Europe, thus increasing competition in the metering market.
- Secondly, the Energy Services Directive[61] (adopted in 2006) requires Member States to develop plans for achieving targets for saving energy from end users and recognizes the importance of electronic metering: "*In defining energy efficiency improvement measures, account should be taken of efficiency gains obtained through the widespread use of cost-effective technological innovations, for instance electronic metering.*"

The provisions of Directive 2006/32/EC regarding metering and billing are generally contained in Article 13[62]. On metering, it stipulates that when meters need replacing, or for all new buildings, households should be "*provided with competitively priced individual meters that accurately reflect customer's actual energy consumption and that provide information on actual time of use*". However, this is caveated by stating that such meters will only be supplied "*if it is technically possible, financially reasonable and proportionate in relation to the potential energy savings*". Nevertheless, Member States may subsidise "*improved metering and informative billing*" [63].

On billing, Directive 2006/32/EC requires that, where appropriate, billing is based on actual energy consumption and shall be performed frequently enough to enable customers to regulate their own energy consumption. In defining energy efficiency improvements it states that account should be taken of the cost-effective technological innovations, for instance electronic metering.

Two points are worth noting:

a) Directive 2006/32/EC does not require smart metering and

b) it is for Member States to interpret what steps are necessary to comply with the Directive.

In this context, many EU countries consider smart metering, combined with time-of-use tariffs, as an optimum way of meeting the requirements of the Directive. In fact, energy efficiency is a major driver for smart metering policies in Europe.

In the "Communication from the Commission - Action Plan for Energy Efficiency: Realising the Potential"[64] the European Commission announced the intention to "*propose more detailed metering and billing requirements (2009)*".

In the recent "Communication from the Commission to the Council and the European Parliament on a first assessment of National Energy Efficiency Action Plans as required by Directive 2006/32/EC on Energy End-Use Efficiency And Energy Services"[65] the European Commission recognizes the importance of smart metering:

> "Member States can encourage energy savings in all sectors by raising awareness of the need for taking action and the practical possibilities available. The Directive requires Member States to ensure that information on energy efficiency mechanisms and financial and legal frameworks is

60 Directive 2004/22/EC of the European Parliament and of the Council of 31 March 2004 on measuring instruments.

61 Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC. OJ L 114, 27.4.2006

62 Article 13 of Directive 2006/32/EC on Energy End-Use Efficiency and Energy Services should be read in conjunction with Articles 1 (Purpose), 2 (Scope), 3 (Definitions) and 6 (Promotion of Energy End-Use Efficiency and Energy Services).

63 Article 11, first paragraph.

64 SEC(2006)1173, SEC(2006)1174, SEC(2006)1175. COM(2006) 545 final of 19.10.2006

65 COM(2008) 11 final of 23.1.2008

> transparent and widely disseminated to relevant market actors, and to promote energy end-use efficiency. They should ensure that information on best energy savings practices is widely available. Such information measures, coupled with clear price signals, tariffs encouraging energy efficiency and better feedback on actual consumption, through improved billing and **smart meters**, should put end-users in a position to take better-informed decisions on their energy use and on taking up energy efficiency incentives."

Current and proposed EU legislation suggest that advanced smart metering is considered part of Europe's future energy policy.

Directive 2005/89/EC of the European Parliament and of the Council of 18 January 2006 concerning measures to safeguard security of electricity supply and infrastructure investment [66] suggests that Member States shall promote "*encouragement of the adoption of real-time demand management technologies such as advanced metering systems*".

The European Commission's third energy liberalization package proposals from 19 September 2007[67] contain new provisions related to consumer rights which seem to imply a need for smart metering. In fact, the Commission's proposal amending the Electricity Directive adds several customer rights to Annex A; stating that customers shall:

> "(h) have at their disposal their consumption data, and shall be able to, by explicit agreement and free of charge, give any undertaking with a supply license access to its metering data. The party responsible for data management is obliged to give these data to the undertaking. Member States shall define a format for the data and a procedure for suppliers and consumers to have access to the data. No additional costs can be charged to the consumer for this service.
>
> (i) shall be properly informed every month of actual electricity consumption and costs. No additional costs can be charged to the consumer for this service."

These proposals are currently subject to review and possible amendment by the European Parliament and Member States. The move towards smart metering is further supported by consumer associations (such as BEUC). Although currently not the case, it may be that new EU legislation mandates improved metering systems for households.

This current lack of European harmonization is in clear contrast with the situation in the USA, where the Energy Policy Act of 2005 (Section 1252) clearly established a new policy in the field of demand response and advanced metering:

> "It is the policy of the United States that time-based pricing and other forms of demand response, whereby electricity customers are provided with electricity price signals and the ability to benefit by responding to them, shall be encouraged, the deployment of such technology and devices that enable electricity customers to participate in such pricing and demand response systems shall be facilitated, and unnecessary barriers to demand response participation in energy, capacity and ancillary service markets shall be eliminated. It is further the policy of the United States that the benefits of such demand response that accrue to those not deploying such technology and devices, but who are part of the same regional electricity entity, shall be recognized."

This policy is articulated around the measures described in the box next page.

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66 OJ L 33 of 4.2.2006

67 Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/54/EC concerning common rules for the internal market in electricity. COM(2007) 528 final of 19.9.2007.

‘‘(14) TIME-BASED METERING AND COMMUNICATIONS.—
(A) Not later than 18 months after the date of enactment of this paragraph, each electric utility shall offer each of its customer classes, and provide individual customers upon customer request, a time-based rate schedule under which the rate charged by the electric utility varies during different time periods and reflects the variance, if any, in the utility’s costs of generating and purchasing electricity at the wholesale level.
The time-based rate schedule shall enable the electric consumer to manage energy use and cost through advanced metering and communications technology.
‘‘(B) The types of time-based rate schedules that may be offered under the schedule referred to in subparagraph (A) include, among others—
‘‘(i) time-of-use pricing whereby electricity prices are set for a specific time period on an advance or forward basis, typically not changing more often than twice a year, based on the utility’s cost of generating and/or purchasing such electricity at the wholesale level for the benefit of the consumer. Prices paid for energy consumed during these periods shall be pre-established and known to consumers in advance of such consumption, allowing them to vary their demand and usage in response to such prices and manage their energy costs by shifting usage to a lower cost period or reducing their consumption overall;
‘‘(ii) critical peak pricing whereby time-of-use prices are in effect except for certain peak days, when prices may reflect the costs of generating and/or purchasing electricity at the wholesale level and when consumers may receive additional discounts for reducing peak period energy consumption;
‘‘(iii) real-time pricing whereby electricity prices are set for a specific time period on an advanced or forward basis, reflecting the utility’s cost of generating and/or purchasing electricity at the wholesale level, and may change as often as hourly; and
‘‘(iv) credits for consumers with large loads who enter into pre-established peak load reduction agreements that reduce a utility’s planned capacity obligations.
‘‘(C) Each electric utility subject to subparagraph (A) shall provide each customer requesting a time-based rate with a time-based meter capable of enabling the utility and customer to offer and receive such rate, respectively.
‘‘(D) For purposes of implementing this paragraph, any reference contained in this section to the date of enactment of the Public Utility Regulatory Policies Act of 1978 shall be deemed to be a reference to the date of enactment of this paragraph.
‘‘(E) In a State that permits third-party marketers to sell electric energy to retail electric consumers, such consumers shall be entitled to receive the same time-based metering and communications device and service as a retail electric consumer of the electric utility.
‘‘(F) Notwithstanding subsections (b) and (c) of section 112, each State regulatory authority shall, not later than 18 months after the date of enactment of this paragraph conduct an investigation in accordance with section 115(i) and issue a decision whether it is appropriate to implement the standards set out in subparagraphs (A) and (C).’’.

Source: Energy Policy Act 2005, Section 1252

3.3 Drivers of smart metering policies

The deployment of smart metering is not an end in itself but rather is a means to reach other objectives. Such objectives differ from country to country, according to policy priorities and to the interests of different stakeholders, as illustrated by the following two examples:

- The first large-scale smart meter programme in Europe (and in the world) was launched by the Italian incumbent utility ENEL in the 1990s. The cost of replacing 30 million electromechanical meters with electronic AMR devices and establishing a new information and communication infrastructure (based on PLC technology) was about 2 billion €[68]. The main objective of ENEL was to reduce “non-technical losses” (i.e., theft) and to be able to effectively control contracted power (which was not feasible with the previous electromechanical meters). According to ENEL’s business plan, the associated benefits justified the large investment (pay-back time less than 5 years). The initial plan was fine-tuned following discussions and negotiations both with the regulatory authority (AEEG) and with consumer associations.

68 www.enel.it/eWCM/salastampa/comunicati/515675-1_PDF-1.pdf

Building upon voluntary industry initiatives (ENEL's example was followed by other distribution/supply utilities), the Italian regulatory authority mandated full introduction of smart meters, established minimum functional requirements and introduced incentives for the adoption of advanced metering features related to quality of supply.

- Sweden was the first country where the legislator mandated the introduction of hourly electricity metering for all customers - in practice, this implies the generalized adoption of smart meters. Sweden has very high per capita electricity consumption: about 15,000 kWh, representing almost 6 times world average and twice OECD average. Therefore, smart meters, providing more accurate consumption information and enabling new contractual arrangements, can contribute to energy conservation, thus facilitating fulfillment of national policy objectives related to energy efficiency and greenhouse gas emissions.

Legislators, regulatory authorities, distribution network operators, retail suppliers and other interested parties (metering companies, meter manufacturers, consumer associations, etc.) may have different reasons to support the introduction of smart meters, depending on country-specific conditions, particular interests and predominant values. However, several global trends converge towards the introduction of smart metering, namely:

- Liberalization of energy markets (in particular full retail competition, as introduced in the EU in July 2007) and evolution of regulatory frameworks supporting more competitive market environments.
- Technology developments, in particular related to ICT.
- Increasing electricity prices and consequent growing consumer interest on possibilities of reducing their electricity bill.
- The need to curb consumption levels, dictated by international policies and commitments related to energy efficiency and greenhouse gas emissions.

Furthermore, smart metering is not an energy-specific phenomenon: it is part of a global trend towards the digital economy and the information society.

The following non-exhaustive table recapitulates key drivers of smart metering policies:

Table 8 Drivers of smart metering policies

<table>
<tr>
<td>• Reduction of end-user electricity consumption through voluntary change of consumer patterns (e.g. switching-off devices instead of keeping them in stand-by modus, buying more efficient appliances, etc.) thanks to better, quantitative information about their impact on the electricity bill.
• Reduction of end-user electricity consumption through new contractual arrangements with the supplier enabling remote control of some consumer appliances (either by the supplier or by the customer).
• Reduction of peak load through new contractual arrangements with the supplier or any third party load aggregator enabling remote control of some consumer appliances.
• Reduction of end-user consumption and/or peak load as a result of the introduction of more cost-reflective (network and end-user) tariffs based on measured data and/or real-time energy pricing.
• Reduction of network losses thanks to availability of more and more accurate information.</td>
<td>Reduction of greenhouse gas emissions</td>
<td rowspan="2">Reduction of end-user electricity price</td>
</tr>
<tr>
<td>• Reduction of “non-technical” losses (theft) thanks to the possibility of real-time monitoring of low-voltage energy flows.
• Fewer bad debts thanks to the possibility of remotely reducing/disconnecting customer load at any moment.
• Easier and faster customer switching procedures.
• Easier comparability of supply offers thanks to better, quantitative information about consumption patterns.
• Better supplier portfolio management thanks to better, quantitative information about customer behavior and possibility of offering new options and services (e.g. remote load management, interruptible contracts, etc.).
• Increased retail competition.
• Reduction of metering and billing costs.
• Better network asset management.
• Lower wholesale and ancillary services market prices as a consequence of increased demand response (via aggregation of low-voltage demand and subsequent participation in these markets).</td>
<td></td>
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</table>

• Possibility of designing and implementing more cost-reflective (network and end-user) tariffs leading not only to more efficient but also to fairer cost allocation among consumers. • Fewer bill complaints thanks to more accurate and more frequent meter reading. • Possibility of introducing new, cost-effective payment options for vulnerable customers. • Better quality of supply thanks to improved network monitoring, faster identification of fault locations and shorter restoration times. • Better quality of supply thanks to the introduction of more effective regulatory incentives/penalties based on measured aggregated and individual variables. • Faster and more accurate information about network outages being provided to customers, also alleviating call center stress. • Remote modification of contractual parameters and connection/disconnection of customers, dispensing with the necessity of customers waiting at home for technical appointments.		**Other customer and general interest benefits**
• Possibility of managing micro-generation and heat-pumps without extra meters. • Possibility of increased penetration of renewable electricity generation thanks to increased demand response (via aggregation of low-voltage demand and subsequent participation in wholesale and ancillary services markets).	**Reduction GHG em.**	

The following excerpt from a speech by PUC commissioner Timothy Simon in October 2007[69] provides useful insights into California's drivers for smart metering:

> Clearly, there is an opportunity in this country to replace old grid technologies with "smart" applications that can communicate with customers and the utility. This ultimately will reduce load and our fossil fuel consumption. The Commission recognized that smart meters are the first step to achieving a smart grid and in 2002 started to develop demand response and advanced metering policies. In 2004, the Commission established three minimum regulatory requirements for approval of the Advanced Metering Infrastructure, or "AMI" project proposals.
>
> These regulatory requirements include:
>
> • AMI systems must meet six minimum functional requirement criteria
>
> • AMI project proposals must be cost-effective
>
> • IOUs must provide a comprehensive plan for implementing their AMI projects, including AMI deployment and system integration
>
> I would like to take a moment to discuss the six functional requirements of an AMI system:
>
> 1. Capable of supporting various price responsive tariffs
>
> 2. Capable of collecting energy usage data at a level that supports customer understanding of hourly usage patterns and their relation to energy costs

69 www.cpuc.ca.gov/PUC/aboutus/Commissioners/06Simon/speeches/071001talkingpointseei.htm

3. Capable of allowing access to personal energy usage data such that customer access frequency did not result in additional AMI system hardware costs

4. Compatible with applications that provide customer education and energy management information, customized billing, and complaint resolution

5. Compatible with utility system applications that promote and enhance system operating efficiency and improve service reliability

6. Capable of interfacing with load control communication technology

Since 2004, all utilities have filed applications to study or deploy advanced meters. The Commission has approved PG&E and SDG&E's requests and is in the process of reviewing Edison's request.

There are three key policies drivers for the Advanced Metering Initiative in California.

• First, in 2003, the CPUC and the California Energy Commission established a loading order for California of preferred energy resources. Demand response is second in the loading order after energy efficiency. Thus, demand response is a very high priority resource in California.

• Second, the Commission has set demand response goals that direct utilities to achieve 5% of system peak from demand response resources by 2007, which is approximately 2,500 megawatts. Today the utilities have approximately 900 megawatts of demand response, which demonstrates the need for advanced meters to tap into new market opportunities to meet these ambitious goals.

• Third, the Energy Action Plan articulated the need to transform California's investor-owned utility distribution network into an intelligent, integrated network enabled by modern information and control system technologies.

To give you an idea of what our advanced metering initiative looks like, here is a current update on the progress of each investor-owned electric utility.

• For Pacific Gas and Electric, the Commission approved a budget for $1.74 billion dollars to retrofit 5.1 million electric meters and 4.2 million gas meters by 2011. PG&E has currently installed 110,000 meters and plans to install about 242,000 by the end of 2007. PG&E, unlike the other utilities, is using a proven technology that meets the CPUC's minimum functional requirements, but does not have the full range of communication capabilities that are available in the marketplace today. Unlike the other utility proposals, PG&E's meter retrofits the old meter instead of replacing it. Next month, PG&E plans to file another application requesting more funds to upgrade their electric meters with communication capabilities similar to the other utilities.

• The Commission approved San Diego Gas and Electric's application last April for $572 million to install 1.4 million solid-state electric meters and 900,000 gas meters. These new solid-state meters will replace old mechanical meters. SDG&E is currently selecting their technology and vendor through a competitive request for proposal. SDG&E will select a vendor by the end of the month and will seek Commission approval to roll out the program next September, with a two and half year deployment time period.

• Southern California Edison submitted their advanced metering application last July and the Commission is currently reviewing their request. Edison has requested $1.7 billion to install 5.3 million solid state electric meters that will replace the old mechanical meters, similar to SDG&E. Edison is looking at a 4 year deployment time period, from January 2009 to December 2012.

While the advanced metering initiative will cost ratepayers billions of dollars over the next 5 years, each utility had to demonstrate that the benefits outweighed the costs in order to receive Commission approval. In addition, these infrastructure upgrades have great economic benefits, including but clearly not limited to creating thousands of jobs in California.

Looking forward, I believe this Commission needs to look beyond smart meters and transition our old grid to a state-of-the-art, twenty-first century transmission and distribution system. Modernizing our grid is essential if California, as Governor Arnold Schwarzenegger refers to as our nation state, or the world's eight largest economy, is going to remain a leader in the global economy. The state and electric industry need to work together and form public-private partnerships to determine which technologies are emerging or available in the marketplace today. We need to determine which ones are the most cost-effective, and which ones we need to deploy in order to meet this state's population and electricity growth. We need to keep our businesses competitive by minimizing outages and promote integration of intermittent renewables or distributed generation in order to meet our environmental goals and reliability needs. My vision is to help lead this transition in a comprehensive and well-thought out manner that takes a long-view on where we are today and where we need to be if we are going to continue providing reliable electricity services that exploit clean energy sources.

As for additional steps to promote smart grid development and deployment, regulators should investigate what types of financial incentives can be provided to companies who undertake the development of smart grid technology. Since there is a degree of risk inherent in new technology, any returns on the investment that can be offered will impact the degree of capital outlay. Yet the concept of financial incentives is more than just minimizing risks. The regulators will want to look for smart energy technologies that have ratepayer benefits such as improved energy reliability and efficiency, as well as environmental benefits in the form of emissions reductions.

Regulators have been asked to consider decoupling profits from electricity sales. Utility companies have argued that utility ratemaking sets pricing and revenues on the basis of cents per kilowatt hour. Thus there is a reluctance to utilize new technologies because of the potential reduction in the amount of energy sold. With decoupling, the regulatory agency can eliminate the disincentive towards energy efficiency or other demand-side management technologies. California instituted decoupling in the 1970s and has benefited greatly from this policy decision.

3.4 Regulatory and legislative tools to promote smart metering

As indicated in Section 3.2, there is no EU legal framework concerning metering in general or smart metering in particular[70]. Therefore, the conditions under which metering activities are performed—including the decision to mandate or to promote smart metering—are established by the legislator (e.g. in Sweden) or by the regulatory authority (e.g. in Italy), according to the national legal framework of each EU Member State.

It is important to point out that EU energy markets are now fully liberalized and all consumers are free to choose their supplier. Therefore, smart metering must be seen in this context of full market liberalization. In other countries where energy markets have not yet been liberalized—or, at least, where full retail competition does not exist—smart metering may be approached in different ways.

The choice of legislative and regulatory tools to promote smart metering depends not only on the (national) legal framework and on the stage of market liberalization, but also on the public or industry motivation for smart metering (see previous Section describing key drivers of smart metering policies).

The type of metering regime (regulated or liberalized) can influence the actual benefits realised from smart metering and their cost effectiveness as an investment. In regulated markets, AMM can certainly improve processes and reduce costs offering potential benefits at many different stages of the electricity supply chain. In liberalized markets, many of the same potential benefits also exist (e.g. it is a tool to improve energy efficiency, facilitate customer switching, introduce new services) but system-wide benefits (e.g. improved network monitoring, operation and planning) may need to be better targeted. This is because the potential benefits to the network depend on a large deployment scale of smart meters as well as to how the smart metering integrates with other infrastructure (data storage, communication, asset management) and its uses (e.g. network management, load modeling, power quality monitoring).

Liberalized metering markets in particular need clear policy decisions from government and regulatory certainty regarding key concerns such as asset stranding and standardization, so as not to deter investment. Suppliers also need clarity on whether there will be a government mandate on

70 Although there is a directive on measuring instruments.

rollout. It also requires strong direction and leadership by the regulator in removing technical and commercial barriers to suppliers so as to help make smart meters a reality at domestic level.

Regulatory and legislative tools to promote smart metering may be divided into three categories:

a) Enabling or mandatory decisions
b) Metering related regulation
c) Other forms of regulation with an impact on smart metering

Enabling or mandatory decisions

In most EU Member States, as indicated in Section 2.1, metering is a regulated activity: only some designated undertakings are allowed to perform metering activities (i.e., they are metering monopolists) and their performance is subject to regulation (including the establishment of allowed revenues and corresponding—explicit or implicit - metering tariffs).

In a few countries, metering is a competitive, liberalized activity: everyone can enter the metering market and there are no regulated metering tariffs.

Independently of the metering regime adopted—regulated or liberalized—the government or the parliament may decide to promote or to mandate smart metering, enacting appropriate legislation establishing, for instance, a deadline for the replacement of all electromechanical meters. In principle, regulatory authorities are able to take similar decisions only in the regulated metering regime.

Legislators and regulatory authorities may take different approaches, such as:

- Just removing any legal or regulatory barriers to smart metering, thus enabling—but not mandating—smart metering.
- Establishing that monthly electricity bills shall be based on measured hourly data, without making any reference to smart metering functionalities.
- Mandating the introduction of smart metering—defined through some minimum technical requirements—and establishing some financial incentives or compensation for the concerned undertakings.
- Mandating the introduction of smart metering without establishing financial incentives or compensation for the concerned undertakings.

Metering related regulation

Roll out obligations are not (yet) a frequently employed instrument. Where they have been implemented or are planned they are usually combined with specific regulatory tools covering technical, procedural and financial aspects. Of course, some of these regulatory tools may be applied even where roll out obligations have not been introduced.

As regards technical issues, the most common approach consists in defining standards or minimum requirements concerning (see Section 3.6 below):

- Meter design (e.g. which variables should be measured, which information should be locally displayed, etc.).
- Meter operation (e.g. how data may be transmitted, communication protocols, frequency of meter readings, etc.).

Irrespective of whether the metering market is open to competition or regulated, setting minimum functional requirements or technical standards will facilitate interoperability, allowing the customer to switch supplier without facing technical barriers. Where the meter market is open to competition it is up to the supplier or customer to decide on the type of meter. It is therefore necessary to provide for certain levels of standardization and interoperability.

Moreover, some performance requirements may acknowledge the importance of smart meters to efficiency of the system as a whole.

Regulation of metering procedures concerns, for instance, access to data (by the consumer, suppliers, distribution network operator, etc.).

As regards financial aspects, there are two basic approaches:

- Granting financial incentives for roll out, dis-incentivising installation of electromechanical meters, co-funding of operational expenses, etc.
- For example where metering tariffs are set by the regulatory authority (either as a separate tariff or as part of the network tariff), the regulator may incentivize the installation of smart meters by allowing a higher meter tariff for smart meters.
- No distinction is made between smart metering and metering in general[71].

Other forms of regulation with an impact on smart metering

A conservative view about smart metering, considering it just a more or less costly device replacement process offering some new features, misses the point: smart metering is a revolutionary development that will radically change the way electricity markets work and networks are regulated.

Smart metering makes available a whole new set of information that enables:

- market participants (consumers and suppliers) to reshape their contractual arrangements, thus reinventing wholesale, ancillary services and retail markets;
- system and network operators to improve overall efficiency, reliability and quality of supply;
- regulatory authorities to introduce better regulation.

A progressive view about smart metering recognizes that it may produce very substantial gains to customers and to society and acknowledges that in order to allow the potential benefits of smart metering to fully materialize, regulation must undergo a deep review process. Furthermore, it recognizes that current performance-based regulation is imperfect due to lack of accurate information, especially at distribution level, and admits that more accurate information obtained thanks to smart metering will enable better (performance-based) regulation.

Current regulatory imperfections lead to inefficiency and distort a fair cost-benefit analysis of smart metering. Let us illustrate this statement with four examples:

- In most countries, low-voltage customers pay flat, time-independent network tariffs. Obviously, this does not give any incentive to customers to reduce demand at peak times and leads to inefficient use of network assets. Smart metering enables suppliers to offer time-of-use tariffs, rewarding those customers who are willing to reduce demand at peak times. However, if network tariffs are flat, these customers will not get any benefit from a more efficient use of networks, in fact subsidizing those customers who stress the network at peak times. In practice, flat network tariffs will reduce the margins of the more efficient suppliers, distorting competition in favour of the less efficient suppliers.
- In some countries, network operator revenues increase with electricity consumption. Therefore, these network operators have no reason to support any measures aimed at reducing electricity

71 For instance, the Norwegian regulatory authority (NVE) considers that "Mandatory roll-out of smart meters should be financed within the ordinary income regulation. No extra financial incentives are regarded as necessary." www.nve.no/FileArchive/185/Englesk%20notat.doc

demand. Regulation can decouple network revenues (income) from electricity consumption, thus facilitating the support—or, at least, non-opposition - of network operators to demand response initiatives and smart metering.

- Load profiling does not give any incentive to demand-side management.
- Smart meters enable low-voltage demand to participate in reserve and ancillary services markets. However, participation of individual low-voltage customers would not be technically feasible and would not be economic due to too high transaction costs. Low-voltage demand participation is feasible through load aggregation. However, in many countries the existence of load aggregators and the possibility of their participation in ancillary services markets is not foreseen, thus preventing the achievement of very important gains in economic and security of supply terms.

Very often, cost-benefit analysis of smart metering underestimates both the current cost of incomplete information and imperfect regulation and the value of future, more accurate and more complete information obtained from smart metering.

As shown by the examples above, regulation can indirectly facilitate—or obstruct - the development of smart metering in many different ways.

In this context it is important to recall ERGEG's recommendation on customer switching[72]:

> "The customer should only need to be in direct contact with one party, preferably the new supplier, when initiating the switch. There should normally be a written contract between the customer and the supplier. Contracting should however be possible electronically, e.g. through the internet, to facilitate switching. There should be regulations on the information needed to be able to switch, for instance name, address and metering point identification number."

As previously stated, smart meters are the visible face of a new information and communication technology (ICT) infrastructure being introduced in electricity systems: smart meters are a key element of smart grids. On the other hand, smart grids enable the potential benefits of smart metering to be fully exploited.

Smart grids are fundamentally different from current passive distribution networks. Therefore, they require new, innovative forms of regulation, as recently recognized by energy regulators in the USA (see box on next page).

Another aspect deserving careful analysis is the potential positive impact of smart metering upon retail markets. In fact, until now, EU policy-makers and regulatory authorities have dedicated more attention and resources to wholesale markets than to retail markets - somehow considered to be more "natural" or "spontaneous" than the former and not needing any particular guidelines. However, this vision is not endorsed by all.

The European electricity industry considers that some guidelines are needed:[73]

> "In view of the crucial role retail markets play in the development of electricity markets, the European Commission, the Member States, the regulatory authorities, with the involvement of all stakeholders, need to establish a political process that will look at putting in place a comprehensive and coherent retail market roadmap for Europe. (…)
>
> Retail market design is ultimately decided upon by political decision-makers and regulatory bodies. Many elements of a common market model can only be realised through regulation

72 ERGEG. Supplier Switching Process Best Practice Proposition. July 2006. www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/CEER_ERGEG_PAPERS/2006/Advice/E05-CFG-03-05.pdf

73 EURELECTRIC. Reference 'Retail Market Model': Bringing the Benefits of Competitive Electricity Markets to the Customer. April 2007.

relating to noncompetitive activities, as these do not by themselves carry incentives to evolve along the lines of the proposed competitive retail market model. In other words, alignment of this reference model with DSO and TSO operations, the creation of favourable balancing, settlement and metering systems, as well as some aspects of consumer protection should be carried out by national governments and regulators.”

Federal, State Regulators Convene Collaborative Dialogue on ‘Smart Grid’

State and federal regulators announced today they will convene a collaborative dialogue on facilitating the transition to a smart electric grid.

The collaborative project will be co-chaired by Commissioner Suedeen Kelly of the Federal Energy Regulatory Commission (FERC) and Commissioner Frederick Butler of the New Jersey Board of Public Utilities. Butler also is first vice president of the National Association of Regulatory Utility Commissioners (NARUC).

The Smart Grid concept involves automating the electric grid. This may be achieved by outfitting the grid with smart controls, two-way communications systems, and sensors. It has the potential to reduce power consumption through demand response, facilitate grid connection to intermittent power stations and distributed generation projects, enable storage of electricity, and improve grid reliability.

“This is an important step in helping to translate the tremendous benefits from the revolution in information technology to our nation’s power system,” FERC Chairman Joseph T. Kelliher said. “Meeting our future energy needs requires new generation and transmission capacity, demand response and conservation and efficiency. This is an excellent opportunity for us to work with our state colleagues on an important emerging issue, and I am pleased that Commissioner Kelly has agreed to lead this effort on behalf of FERC.”

“This dialogue will give us an avenue to seek ways to reverse the under-investment in advanced technology applications for our power generation and transmission systems,” Commissioner Kelly said. “Our nation’s electricity needs continue to grow dramatically, and we can address our needs in an efficient, environmentally conscious and consumer-friendly way by focusing on the Smart Grid.”

“Developing the Smart Grid will help modernize our electricity delivery system and may empower consumers with the means to take more control over their energy consumption,” said NARUC President Marsha Smith of Idaho. “As we face growing demand and rising electricity prices, we must make the grid as efficient as possible. Doing so requires a strong working relationship with our federal colleagues and we are excited to participate in this important collaborative.”

“State regulators are heavily invested in this issue because we stand closest to the ratepayers who will benefit from the Smart Grid,” Commissioner Butler of New Jersey said. “It is important that we work closely with our federal counterparts and this collaborative effort will provide all of us with a venue to move forward.”

Source: http://www.ferc.gov/news/news-releases/2008/2008-1/02-14-08.pdf

Along the same lines, the International Energy Agency provides the following diagnostic and recommendations[74]:

“It was expected that the liberalised market would deliver increased innovation in the retail pricing options and that, for example, new Energy Service Companies (ESCOs) would emerge at the retail end of the market.

In many OECD electricity markets this has not happened. Consumers have been free to choose: to choose a lower price; to choose a bundled product; or to choose a new billing or customer service offering. However, energy services and energy efficiency have yet to take their place on the landscape of retail offerings and therefore in the minds of electricity consumers. (…)

74 IEA. “The power to choose - demand response in liberalised electricity markets”. 2003

> The public good attributes of network reliability and security call for clear guidance to market participants regarding the maintenance of minimum acceptable standards. Despite the potential for demand response resources to contribute to reliability and security objectives (often a least-cost solution), this study has shown that the potential has yet to be realised. One potential remedial policy intervention would be to place an obligation on retailers for them to develop a particular amount of demand responsive load. Similar obligations have been placed on retailers for the acquisition of renewable power. (…)
>
> Dealing adequately with the demand-side will require changes to current regulatory models in liberalised electricity markets. Regulatory instruments and policy measures for electricity markets have been introduced to deal with the relatively concentrated and well-known industries of supply and transmission. Retail regulation has focused on matters of consumer protection and ensuring that the ultimate cost to the consumer is a fair reflection of the long-term marginal cost of supply.
>
> An initial and practical step towards unlocking the potential contribution of the demand side will be to establish quantifiable demand response targets. Regulators should be able to test the responsiveness of the demand side, in much the same way as it is able to do so for the supply side. In so doing regulators will be better placed to ensure system reliability and public good objectives.
>
> In addition regulators should re-visit market power test procedures and ensure that the potential benefits of demand response to limit market power abuses are duly recognised."

Even within a national regulated metering market with a single distribution network operator (responsible for metering) moving to smart metering requires adjustments (administrative processes and information systems), which could result in heavy reliance on existing applications (in favour of the incumbent supplier) or the delayed introduction of smart meters. It is important that the distribution network operator's information systems are well prepared for the introduction of competition (to the incumbent supplier) and would enable implementation of procedures compatible with smart metering.

In countries where there are multiple distribution network operators (responsible for metering) there is even greater scope for different treatment of suppliers and customers. In the absence of a technical or legal requirement to install smart meters in households, some distribution network operators (or suppliers) will voluntarily install meters whereas others will not. This can lead to a non-homogenous treatment of customers and suppliers and interoperability issues.

3.5 Case studies of regulatory tools: Italy, the Netherlands, France

Before examining some individual case studies of regulatory experiences in Europe, it is useful to recall that regulated metering prevails over liberalized meter services. Consequently a range of regulatory tools can be easily used to actively promote smart metering—such tools can be introduced individually or in combination with other policy options such as mandatory roll-out obligations, or requiring more frequent meter reads or bills based on actual consumption. The regulatory toolkit for promoting smart metering includes not only financial incentives, performance requirements and functional requirements or technical standards, but also indirect measures creating a level playing field for smart metering (see previous Section, *Other forms of regulation with an impact on smart metering*).

3.5.1 Italy

Italy has had a long experience with a large deployment of smart meters on a voluntary basis (i.e. before the regulatory framework was developed). Italy also provides a practical example of a mix of regulatory tools that can be used to promote the rollout of smart metering. This includes mandatory roll-out obligations, financial penalties for non-replacements, and the specification of minimal functional requirements by the regulatory authority and the use of performance requirements.

Italy is also a good case study of the application of smart meters to pursue different objectives. For example, financial incentives are given for the use by distribution network operators of smart meters for quality of supply purposes. Smart meters are also used in Italy (and in the Netherlands) for managing bad debt through remote reduction in the capacity made available to the bad debtor and remote disconnection/re-connection.

Policy Objectives

1. Developing competition in supplying electricity to low-voltage customers.
2. Transferring to the customer as much as possible of the benefit accruing from conducting business remotely (opex reduction)
3. Lowering the interval metering (to 1hr) for low-voltage customers.

Regulatory Tools

For a number of years, some distribution network operators (e.g. Enel[75]) had already being installing electronic meters and automated meter management (AMM) systems. However, this was absent any common standards. Following a public consultation in 2006 the Italian regulatory authority (AEEG), tried to redress this by introducing[76] the mandatory roll out of smart meters, which must now comply with minimum functional requirements, for all low-voltage customers. Starting from 1 January 2008, for each low-voltage customer, distribution network operators shall install one single smart meter, single phase for single-phase applications, and three-phase for three phase applications.

The regulatory authority decision requires all distribution network operators to install smart meters over a four year period (2008-2011), on a percentage basis of their overall installed power, irrespective of the number of customers served:

Mandatory timing for low-voltage customers	%	Installation date	Commissioning date
Household and non-household with power ≤ 55kW	25%	31 December 2008	30 June 2009
	65%	31 December 2009	30 June 2010
	90%	31 December 2010	30 June 2011
	95%	31 December 2011	30 June 2012
Customers with power > 55kW	100%	31 December 2008	30 June 2009

75 ENEL is the largest DSO with a customer base of more than 30 million low-voltage customers, accounting for 85% of low-voltage customers. It voluntarily started installing smart meters at low-voltage level in 2001. However it used proprietary technology resulting in a lack of interoperability. The Italian regulator has subsequently introduced (in 2006) mandatory upgrading by all distribution network operators of meters at low-voltage level which must comply with minimum functionality. In the context of the legacy of ENEL being an early mover, the regulator has recently commissioned a study (results expected in summer 2008) which will benchmark communication protocols, transmission media and functions currently used or available in Europe and will examine inter alia the capability of meters currently on the market to adopt EU (e.g. CEDEC, CENELEC) and non-EU (e.g. IEC) communication protocols, and the adoptability of a communication standard from smart meters currently in use in Italy.

The distribution network operators in Rome and Brescia also voluntarily started installing smart meters at low-voltage level in 2005. All high-voltage customers and medium-voltage customers have interval meters (15min -1 hour) and are treated on an hourly basis.

76 Regulatory Order No. 292/06 (of 18 December 2006) was modified by Regulatory Order 235/07 (of 26 September 2007) which introduced deadlines for the commissioning of smart meters and also performance requirements of AMM systems.

Since 2004, the metering service tariff is separated from the distribution tariff and is set so as to cover the investment cost of smart meters for low-voltage customers. To avoid “free-riding” (in light of the single national tariff that reflects significant investments to upgrade the meters of low-voltage customers in recent years), for the regulatory period 2008-2011, such remuneration will be approved only for distribution network operators that have actually invested in these technologies.

Furthermore to ensure compliance with the new mandatory rollout, the regulatory authority introduced a financial penalty (by curtailing the allowed revenue paid to the distribution network operator for metering service) if it fails to meet the installation plan. For example, if by 1 January 2009, a distribution network operator had equipped 18% of its low-voltage power with electronic meters, it would not receive the allowed metering revenue for the 7% shortfall of the 25% mandatory target. There is no incentive for exceeding the installation timetable.

The regulator has introduced a financial incentive for distribution network operators who use smart meters and AMM for quality of supply purposes. From 2008 (gradually, depending on the size of the distribution network operator), the distribution network operator is required to keep records of all low-voltage customers subjected to a long (i.e. > 3 minutes) unplanned interruption. The distribution network operator may choose information systems (e.g. GIS), which comply with minimum standards set by the regulator, or they may choose smart meters. If the distribution network operator chooses to install electronic meters and AMM systems, it receives a financial incentive (of 15 Euro per customer). To qualify for this quality of supply incentive the distribution network operator must roll out the smart meters to a faster timetable than the general mandatory rollout timetable (i.e. the distribution network operator must have commissioned smart meters in 85% of the total number of low-voltage withdrawal points as opposed to 65% by 30 June 2010).

The regulatory authority has specified minimum requirements (meter and system capabilities) in the pursuance of smart metering policy objectives, to guarantee the same options to all customers and to ensure interoperability. These minimum requirements are geared mainly towards the system as a whole rather than at the level of the meter or other individual parts. Main functional requirements (AMM) relate to:

- time of use price schemes and weekly profile - up to four bands and five intervals during the day in which to apply the four bands;
- interval metering capabilities -depth of 36 days;
- security of withdrawal data—inside meters during the transmission to the control centre and meter must also be equipped with a status word programme that signals meter failure promptly to the control centre;
- remote transactions—periodic readings for billing purposes, reading of interval metered data, activation/deactivation, change in contractual power, change of price, power reduction;
- freezing withdrawal data—billing, contractual changes, switching;
- meter display—although often assumed, smart meters don’t naturally provide a display of the information to the customer;
- upgrade of the programme software;
- reading information on slow voltage variations (according to EN 50160).
- By Order no. 235/07 of 26th September 2007, the regulatory authority introduced performance requirements of AMM systems:
- annual percentage of successful remote transactions (activation/deactivation, change of subscribed power, change of price scheme, power reduction) within 24 hours and within 48 hours;
- failure rate in readings reported to the control centre.

- In January 2008, the regulatory authority commissioned a consultant to conduct a study on smart metering and demand response, the results of which are expected in summer 2008.

3.5.2 The Netherlands

Metering Regime—from liberalised to regulated?

The Netherlands has since 2000 a liberalized metering market whereby metering is a free activity but this appears to be set to change by 1 January 2009, when the Netherlands is expected to revert to being regulated again. This is subject to a Parliamentary discussion in May 2008 when legal proposals for a restructuring of the Dutch metering market are expected to be adopted. A principal driver for this reform of the Dutch meter market is a fundamental energy efficiency goal for residential customers and the transposition of the Energy Services Directive.

Smart Metering Policy

The Dutch liberalized metering regime has not been very successful in terms of the installation of smart meters (about 3% currently). Driven largely by energy efficiency goals, in 2006 the Dutch Ministry of Economic Affairs submitted a "policy intention" addressing the restructuring of the metering market for small energy users.

These upcoming changes in the metering market in the Netherlands (to be adopted in law in 2008) will have a profound impact. From 2009-2014 all households will be given a smart meter for electricity (which will also read gas and water) that must comply with basic functionality (specified in NTA-8130). Currently the distribution network operator/metering company and supplier can own and install the meter. With the new metering market regime, from 2009 only the DSO will own the meter, the metering system (i.e. all the intelligence that is used for communication and control) and the "central access server" (CAS[77]). The meter will form part of their regulated asset base (except the legacy meters[78]) and regulated metering tariffs will apply.

The distribution network operators will be responsible for planning the rollout which will be monitored by the regulator. During the initial stage of the rollout, the supplier will be given some influence on rollout prioritization. The supplier will still be able to install smart meters so long as it is compatible with NTA-8130 and it doesn't interfere with the distribution network operator rollout plans[79]. The supplier will be reimbursed by the distribution network operator. From 2009, the supplier will be responsible for the reading of the old and new smart meters and the processing of metering data and will select a recognized metering data company for implementation of the above proposals. Old meters will remain in the system for 6 years (until 2014) when the national smart meter rollout should be completed. The regulatory authority may, after the parliamentary discussion in May, consult on key issues such as financial incentives to promote the rollout of smart meters or how to give legal

77 The CAS allows the metering system to be remotely read and controlled. It is the gateway to/from the customer for all market parties including the energy suppliers and independent service providers (ISPs) who provide commercial services such as smart home appliances.

78 Oxxio has on its own initiative rolled out approximately 100,000 smart meters since 2004. For a 15 year period, suppliers of these kind of legacy meters will be allowed keep their meters and they will get some compensation reimbursement from their DNO.

79 Metering installation has been defined as consisting of installing at the customer's premises:

One or more metering instruments (equipment with a measurement function) at least for electricity and normally also for gas, and sometimes also for water and thermal energy; and

The metering system, which has been defined as the metering installation without the separately installed metering instruments.

status to the voluntary National Technical Agreement (NTA) which specifies minimum functional requirements.

Functional Requirements and Communications Protocols

In connection with the reforms, in April 2007 a new Dutch smart meter standard - National Technical Agreement (NTA-8130) - for the household meter market was defined by the Netherlands Standardization Institute (which also includes communication standards). The minimum functionality required in the smart meter includes:

- Remote reading of the energy consumption (both periodic, actual and interval values);
- Remote reading of the electricity supply (both periodic, actual and interval values) –for individual (decentralized) generation;
- Monitoring of the quality of the electricity supply (outages, voltage swells and sags);
- Registration of violation and fraud attempts;
- Remote activation and deactivation of the energy supply;
- Temporarily limit the electricity supply by setting a threshold;
- The possibility to connect external services devices;
- Sending short messages to the display of the meter;
- Sending long messages to the meter for on-line interaction—these will be forwarded to the external devices;
- Status information (errors, tariff indicators, breaker and valve positions, thresholds);
- The possibility of firmware updates; and
- The provision of access and security.

Several additional functional requirements were also defined such as the average voltage level at the customer's premise and requirements regarding life expectancy. A number of quality and performance criteria have been defined with respect to the (maximum allowed) data retrieval time and handling times of the metering system.

In order to operate the meter, a number of communication interfaces have been defined:

P1 interface - for the communication between the metering installation and one or more other service modules (e.g. external displays, which might be a part of the service package of an ISP).

P2 interface - for the communication between the metering system and one or more metering instruments and/or grid operator equipments (e.g. gas, water, and heat meters)

P3 interface - for the communication between the metering installation and the Central Access Server (CAS).

P4 interface—the port on the CAS through which the distribution network operator, suppliers and independent service providers (appointed by the consumer) gain access to the CAS.

This meter definition and communication protocols enforces both interoperability and compatibility between the systems of the various grid companies

3.5.3 France

Study on possible roll-out of smart metering at LV level

In France the regulatory authority (CRE) commissioned an international benchmark which included a study of the various technologies which could be deployed in France and a cost-benefit analysis, as well as the development of a business case for the application of a remote meter reading solution for all low-voltage meters in France[80].

The study shows that, even if the economic benefit of AMM is neutral or only slightly positive for the distribution network operator, the positive impact on electricity supply and generation costs could be significant [81]. In terms of the cost-benefit analysis[82], the study also shows that consumers should also benefit both directly (supplier switching is made simpler and so supply prices decrease with improved competition) and indirectly (not having to be at home for operations such as meter reading, change of subscribed power, or reconnection).

Objectives

Following this report and the announcement by one distribution operator (ERD, a subsidiary of EDF) of a large scale metering system pilot project, the regulatory authority issued a communication[83] outlining its policy guidelines for the deployment of smart meters at low- voltage level. In it, the regulatory authority outlined that any planned installations by distribution network operators of upgraded metering systems must meet the objective of improving conditions for electricity market operations and must allow a diversification of offers and efficient handling of the demand. Also in June 2007 the French Senate recommended a mandatory roll-out of smart metering, indicating political interest in smart metering (but importantly such recommendations do not carry any legally binding weight[84]).

However, the regulator's June 2007 communication will act as the basis for a decree (provided for in French law), drafted by the regulatory authority for proposal to the government, for managing the deployment of systems for remotely managing meters and metering data at household level. This decree could establish a mandatory roll-out within defined timeframe and also the means of bearing the financial costs of the systems.

In this regard the regulator is awaiting the results of ERD pilot project involving 300,000 smart meters which will test different technical solutions in 2 areas (town and country). This experiment will be subject to assessment (end of 2010) of a Consumer Working Group (GTC) comprising distribution network operators, consumers and suppliers with a review board (chaired by the regulatory authority) responsible for checking compliance with the June 2007 guidelines. Subject to the regulator's proposed decree on whether or not to have a mandatory roll-out, and if so fulfilling which conditions (and government's final decision), smart metering at low-voltage level could potentially be rolled out on a mass scale. [85]

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80 International benchmarking of remote meter reading and remote management systems and a technical and economic study aimed at assessing the conditions of transformation of the current metering equipment", by Capgemini Consulting, 8 March 2007, on www.cre.fr.

81 The study showed that benefits in terms of supply would result from improved customer relations (bills based on actual measures, fewer complaints, possibility of billing a part of non-technical losses, and reduction in numbers of unpaid bills). For generation, the upgraded metering system can usefully contribute to control of consumption peaks and therefore to reduction in average generation costs.

82 The cost-benefit analysis depends on the choice of the scenario. Overall, the three scenarios display higher differences in benefits than differences in cost. However, the conclusions vary depending on the scope in question (distribution only, integrated operator, customers, local community).

83 See CRE Communication (6 June 2007) on www.cre.fr.

84 See French Senate paper on new metering associated to dynamic pricing for supply security on www.senat.fr.

85 On June 3, 2008, the regulatory authority published a proposal for public discussion. This proposal foresees introduction of smart meters for all customers by 2016:
www.cre.fr/fr/content/download/5648/122667/file/080603NTNoteTechniqueConsultationDecretarticle4.pdf

Functional requirements

The regulatory authority's communication from June 2007 concerning changes to low-voltage metering (≤ 36 kVA) firstly specifies minimum functionality conditions and secondly requires that common performance levels and functions be met by distribution network operators allowing all interested parties to benefit from effects of scale. Compliance with these conditions is one of the prerequisites to be met by DNOs in order to get the costs recovered by network tariffs for use of public electricity grids. Specifically the communication requires that the deployment of a generalised remote management system for electricity meters can only be justified if it provides improvements in the three following areas:

- consumer information;
- operation of the electricity market;
- network operators' costs.

To achieve improvements in the operation of the electricity market, the advanced metering system and associated communication and information system must

1. set up a framework that encourages new supply and service offers, whereby the supplier can determine his own supply tariff schedule
2. allow routing of all metering data recorded and measured by the meters. The data concerned are, as a minimum, those relating to energy flows (index, load curve items, maximum value of withdrawn power, etc.) and data relating to quality of electricity supply.
3. improve reliability, rapidity and fluidity of the various market processes (e.g. connection, disconnection, supplier switch, power change, etc.).

To achieve improvements in the grid operators' costs, it must

1. contribute to monitoring the quality of electricity supply
2. reduce the volume of non-technical losses
3. minimise costs of routine and non-routine operations.

3.6 Minimum functional requirements

The EU has no harmonized regulatory framework governing metering and smart metering. However, it should not be concluded that having a mix of regulated and liberalized metering markets in Europe is incompatible with widespread implementation of smart metering. What is problematic is if numerous metering companies (or suppliers in liberalized markets) roll out different, incompatible technologies within a network. This (national) problem may be amplified in an EU context if there is lack of harmonized rules. Irrespective of whether the metering market is liberalized or regulated, standardization and minimum functionality are issues that need to be addressed at least at national level, and preferably with some harmonization at EU level.

Given the fast development of new information and communication technologies, characterized by steadily increasing performances and dramatic changes in relative prices, specification of minimum requirements and harmonization should be carried out at high levels of functional abstraction and not at low levels of technical detail. Several technical solutions may fulfill the same minimum functional requirements, although with different degrees of flexibility, modularity and interoperability and also with different costs.

This current situation of information and communication markets is indeed a strong argument in favor of a liberalized metering regime: the customer chooses the best solution in terms of performance and service, bearing the costs (directly or indirectly via supply contract). In the regulated regime, on the contrary, once the technical solution is determined (by the distribution network operator, the metering company or the regulatory authority), all customers have to do is to pay the respective cost and customer choice in terms of the smart metering device will be reduced. On the other hand, a liberalized metering market requires appropriate regulation of minimum functional requirements in order to avoid new technical barriers to customer switching and to ensure interoperability between different data bases (supplier, distribution network operator, etc.) in order to enable system-wide benefits to be achieved, while in a regulated regime this should be granted by design.

Smart metering can include a number of functions and capabilities such as display and recording of real time information, distinguish between import and export, undertake two-way communication with a central processor, receive instructions and transfer price signals to customers. While the technology is already generally available for these functions, there is a wide range of technology options both in terms of the meters themselves and the associated communication links. On one hand the number and type of functionalities determines the potential benefits and on the other hand it impacts on the cost of the smart metering system.

Scoping out the desired minimum functionalities is a critical first step in developing a smart metering policy. In regulated markets, where the investment cost of installing a smart meter is allowed by the regulatory authority, the regulated meter tariff (or network tariff) should reflect the agreed level of minimum functionality. Moreover, the specification of minimum functional requirements is necessary so:

- as to ensure the pursuance of the same objectives of the smart metering policy and that the core benefits are realised;
- as to ensure interoperability;
- that the same minimum options are offered to all customers (household and non-household), whether they remain under a customer protection scheme or choose to switch to a new supplier, and irrespective of who provides the service.

ERGEG advocated that, irrespective of whether it is a regulated or competitive market regime, regulators should introduce minimum requirements and made a number of recommendations to regulators in this regard including[86]:

- Minimum requirements should apply at system level rather than equipment level, to render them independent from the architectures used by operators or available for purchase.
- Smart metering systems should be qualified by performance levels rather than intervention in their architecture or in the size of the system or any of its parts.
- Meter interoperability is a fundamental pre-requisite.

The definition of minimum functional requirements may concern the following aspects (see Figure 11):

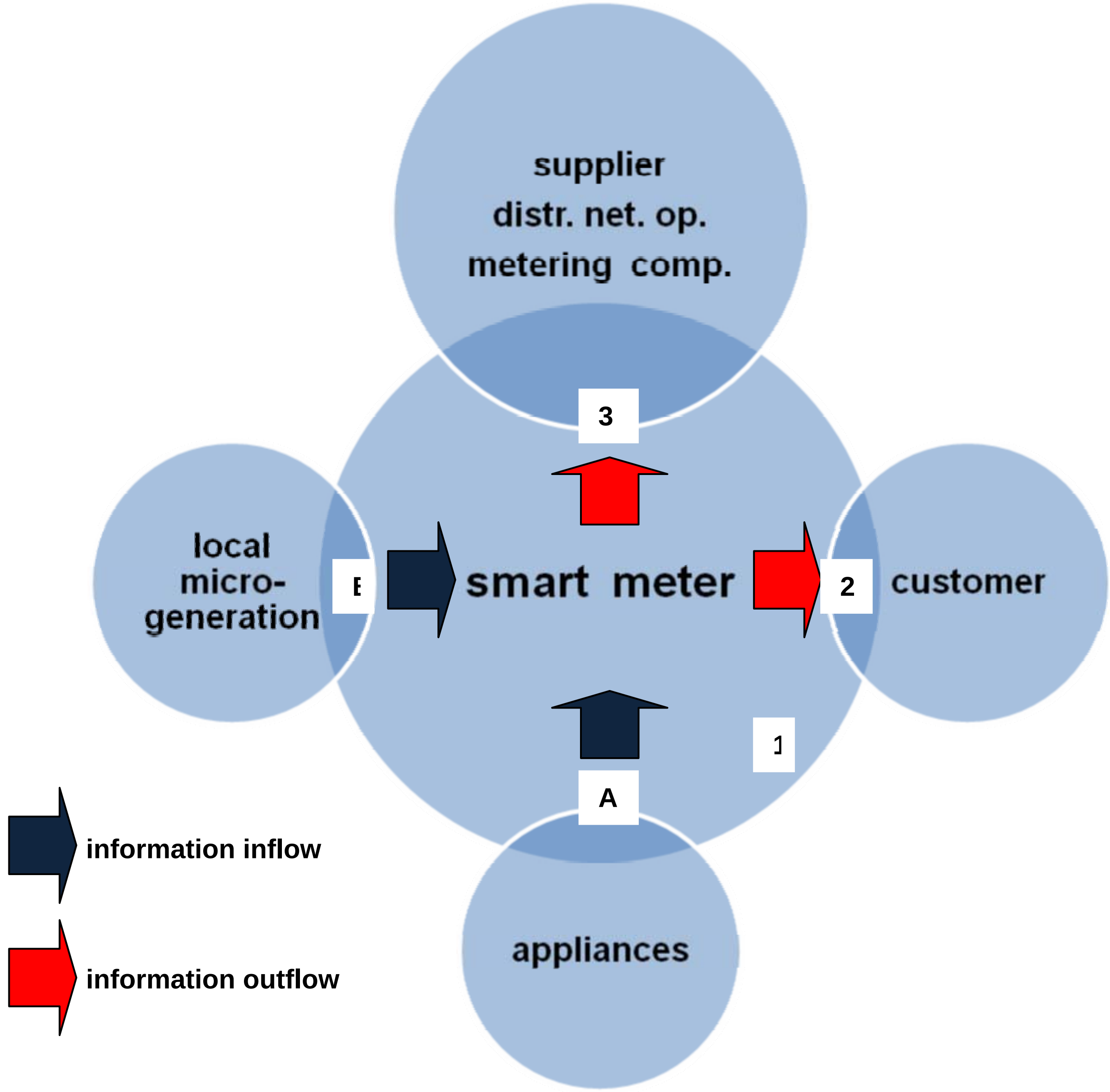
1. The meter itself.
2. The interface between meter and customer.
3. The interface between meter and supplier / distribution network operator / metering company (as appropriate, according to the metering regime).

As regards meter specific requirements, they may concern:

- Information collected at aggregated level, i.e., which variables will be measured: e.g. active power (at which time intervals; multiple timeframes; import and export), reactive power, number of network outages, duration of network outages, maximum demand, number and time duration of deviations from nominal voltage, etc.. Aggregation may correspond to consuming appliances only (A) or include local micro-generation (B) (“net metering”).
- Ability to measure consumption of individual customer appliances.

86 ERGEG. “Smart metering with a focus on electricity regulation”. October 2007. See www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/CEER_ERGEG_PAPERS/2007/Positions/E07-RMF-04-03_SmartMetering_final.pdf

Fig. 11 Smart meter – information flows (one-way communication meters)



- Meter storage capacity (e.g. how many days / weeks / months of measurements can be locally stored without memory overflow).
- Processing capacity (e.g. converting energy consumption into currency or CO2 emissions according to some preset parameters, calculating daily energy consumption, aggregating instantaneous power values into energy values, thus building load profile data, etc.).
- Ability to operate in pre-payment modus.
- Automatic fraud detection.

As regards meter interfaces, two cases are possible: either the meter just provides one-way information to "information consumers" (the customer on one side and the supplier / distribution network operator / metering company, as appropriate, according to the metering regime, on the other side—see Figure 11) or the meter has two-way communication capabilities, also enabling meter and/or device control. Communication protocols should be public and data and control formats should be standard.

As regards the interface between the meter and the customer, this may concern:

- technology (dedicated LCD display, computer, etc.);
- data transmission technology (serial port, optical devices, etc);
- location (central or mobile);
- display forms (tables, numbers, language, graphs, pictures, etc.);
- information contents (consumption by appliance, by room, by time period, by person, etc.; past performance, present real-time values, forecasts);
- ability to remotely control individual consumer appliances (connect / disconnect, load modulation, etc.);
- possibility of sending price signals to customer;
- possibility of on demand metered data access for customer.

As regards the interface between the meter and supplier / distribution network operator / metering company, this may concern:

- data transmission technology (PLC, GSM, GPRS, fixed-line telephone, radio, broadband, etc.);
- characteristics of remote meter reading;
- ability to remotely change tariff parameters (even real-time pricing), metering cycles (e.g. summer and winter periods; weekly or daily cycle, peak / off-peak, etc.), contracted capacity, etc.
- ability to remotely connect / disconnect the consumer;
- ability to remotely connect / disconnect individual consumer appliances;
- ability to remotely control individual consumer appliances (demand reduction);
- possibility of remote firmware update;
- possibility of on demand meter data access for authorized 3rd party;

Currently smart metering policies are set at national level. Furthermore minimum functional requirements (where they are in place) are determined by the objectives of the (national) smart metering policy and the required applications of the smart meters to realise the expected benefits. Consequently, functional requirements are set at national level and differ from country to country, thus potentially creating obstacles to foreign suppliers and metering companies trying to enter new markets.

This raises the issue of whether there should be harmonization of standards at national or EU level. Standards (e.g. metering point IDs or communication protocols) do not have to be set at national level but rather could be required to comply with EU (e.g. CENELEC or CEDEC) or international (e.g. IEC) standards. Harmonization at EU level requires agreement, *inter alia*, on the following points:

- minimum level of functionality;
- how much harmonization is required;
- shall smart meters currently installed adapt to the communication protocols and degree of standardization required ?

4. Recommendations

As rightly pointed out by the European electricity industry some years ago, "The issue of metering, however invisible in the general debate is of paramount importance for the customer, supplier and distributor".[87]

Smart metering is a crucial factor for the efficient functioning of the Internal Electricity Market, as well as for the successful implementation of current EU policies related to energy efficiency, renewable energy and security of supply.

Therefore, smart metering deserves high priority on the agenda of European policy-makers and regulatory authorities.

When considering smart metering initiatives or designing smart metering policies, policy-makers and regulatory authorities should bear in mind the following facts:

- Smart metering is not an energy-specific phenomenon: it is part of a global trend towards the digital economy and the information society. In fact, the "big switch"[88] from analog to digital arrives rather late in the electricity industry, as compared to other industries. As stated in the July 2001 issue of Wired magazine, *"the current power infrastructure is as incompatible with the future as horse trails were to automobiles"* [89].
- Smart metering is not just about replacing old electromechanical meters by new, electronic meters with digital displays and the possibility of remote meter reading.
- Smart metering is the combination of new, electronic meters with a new information and communication infrastructure that provides comprehensive real-time information flows, as well as the possibility of introducing new control loops.
- Smart metering provides a whole new range of complete and accurate information about the functioning of the electricity system at low-voltage level. This physical, operational information, when coupled with information generated by energy markets, enables customers, suppliers and network operators to make better decisions that produce not only individual economic benefits, but also societal, economic and environmental benefits.
- Availability of real-time information and two-way communication channels enables customers and suppliers to manage individual consumption in more effective and efficient terms. Thanks to new information and communication technologies, customers may become active masters of efficient energy consumption, instead of being passive slaves of their energy consuming devices.
- In order to reap the full benefits of smart metering, it is necessary: first, to understand its potential disruptive implications upon the functioning of the physical (network) and economic (market) structures where it will be implemented; second, to reframe networks and markets and to redesign both operational and market processes, taking into account new available information and new demand control possibilities. If networks and markets are considered immutable, pre-established realities, and smart metering is viewed as an add-on feature that must fit into these unchallengeable structures at minimum cost, the case for smart metering is negatively biased.
- The introduction of new information and communication technologies into electricity networks, going beyond smart metering, enables distribution networks to play a more active role in the

87 EURELECTRIC. Report on customer switching in Europe. March 2003.

88 *The Big Switch: Rewiring the World, from Edison to Google* is the title of a recent best-seller written by Nicholas Carr and published by W. W. Norton.

89 Quoted by Clark W. Gellings in the paper "A Power Delivery System to Meet Society's Future Needs" presented at the 2004 IEA Workshop on Transmission Network Reliability in Competitive Electricity Markets.

functioning of electricity systems—i.e. distribution networks become "smart grids". Smart grids make possible considerable economic, environmental and reliability gains. Smart metering is a key building block of smart grids; smart grids allow smart metering to reveal its full potential.

- Today, in the EU, there is a disconnect between fixed end-user pricing and volatile wholesale market prices—i.e., between retail and wholesale markets. Smart metering, enabling customers to participate in wholesale, reserve and ancillary service markets (through aggregation), contributes to a more efficient electricity market.
- Although mandating distribution network operators to rollout smart meters may seem the easiest way to introduce smart metering in a quick and coherent way, it is not necessarily the only or the best alternative. On the one hand, without a proper regulatory framework, distribution network operators may adopt incompatible systems, thus creating new barriers to the development of the Internal Energy Market; on the other hand, network operators do not have the same kind of business motivation as energy suppliers and energy service providers and therefore they will tend to adopt less creative and less flexible solutions. If clear and suitable regulatory principles and technical specifications are established, competition in smart metering is indeed feasible, delivering the same or even better results than a centralistic approach based on the monopoly of distribution network operators.

Considering the crucial importance of smart metering for the proper functioning of wholesale and retail electricity markets and the fact that most EU Member States are only in the process of preparing (or planning to prepare) smart metering policies, the EU should urgently adopt guidelines on smart metering. These guidelines could be proposed by industry and reviewed by ERGEG and they should include the following points:

- Minimum functional requirements, with special emphasis on demand response capabilities and interoperability.
- Definition of technical standards (e.g. communication protocols, Electronic Data Interchange, data exchange between network operators, metering point identification) and respective review and upgrade procedures.
- Mandatory roll-out targets.
- Access to data by customers, suppliers and network operators, avoiding any undue discrimination and ensuring appropriate levels of transparency and confidentiality.

Moreover, the EU should urgently adopt guidelines on the integration of demand response into market design, facilitating load aggregation and participation in wholesale, reserve and ancillary services markets and mandating transmission system operators to promote and to take due account of demand response.

Given the fast development of information and communication technologies, governments and regulatory authorities should stimulate competition among smart metering providers within an EU harmonized framework, instead of imposing specific technologies.

Regulatory authorities should review those regulations that hinder the development of smart metering (e.g. lack of cost reflective time-of-use tariffs) and should actively promote demand response.

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Definitions

Provided by ERGEG ("Smart metering with a focus on electricity regulation"):

Automated Meter Management

Technologies which allow a two-way communication between the meter and the data collector. In comparison to AMR technologies, AMM technologies allow some additional features such as for example:

- to disconnect remotely users (in an emergency or when they leave or move to a new home) or to remotely set a limit on the amount of power or energy to be used;
- to allow energy prices to be remotely changed and to make information on tariff data on
- demand available in the customer's house;
- to allow contractual power to be remotely changed;
- in general to improve customer service.

Automated Meter Reading

Technologies allowing a one-way communication from the meter to the data collector and enabling a meter to be read remotely through a communication system without the costs of manual meter reading. Each meter must be able to reliably and securely communicate the information collected to some central location. Many forms of communication exist and have been explored, like fixed telephone line, SMS (text) messaging, GSM, GPRS, the Internet, radio and power line carrier (PLC). In comparison with traditional meters, AMR entails several improvements:

- to eliminate problems from inaccurate billings, based on estimates;
- to make switching process easier, as accurate meter readings are available when a customer
- changes supplier;
- to detect frauds, by communicating that a meter has been tampered with.

Interval metering

Technologies with AMM allow not only a two-way communication but also store more information (e.g. one or half or ¼ hourly data) which can be collected and sent to the data collector. These smart meters allow suppliers to introduce different prices for consumption based on the time of day, so that customers may be encouraged to move some of their use away from periods of peak demand when electricity is more expensive.

Smart meter

This is a general definition for an electronic device that can measure the consumption of energy (electricity or gas) adding more information than a conventional meter (price schemes, interval data, quality of supply, etc...), and that can transmit data using a form of electronic communication. 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 automated meter reading, automated meter management and a different application mix such as domotics, value-added services, etc..

Provided by FERC ("Assessment of demand response & advanced metering" [90]):

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90 www.oe.energy.gov/DocumentsandMedia/congress_1252d.pdf

Demand

Represents the requirements of a customer or area at a particular moment in time. Typicallycalculated as the average requirement over a period of several minutes to an hour, and thus usually expressed in kilowatts or megawatts rather than kilowatt-hours or megawatt-hours. Demand and load are used interchangeably when referring to energy requirements for a given customer or area.

Demand Bidding/Buyback

A demand response program where customers or curtailment service providers offer bids to curtail based on wholesale electricity market prices or an equivalent. Mainly offered to large customers (e.g., one MW and over), but small customer demand response load can be aggregated by curtailment service providers and bid into the demand bidding program sponsor.

Demand Response

The planning, implementation, and monitoring of activities designed to encourage customers to modify patterns of electricity usage, including the timing and level of electricity demand. Demand response covers the complete range of load-shape objectives and customer objectives, including strategic conservation, time-based rates, peak load reduction, as well as customer management of energy bills.

Direct Load Control

A demand response activity by which the program operator remotely shuts down or cycles a customer’s electrical equipment (e.g. air conditioner, water heater) on short notice. Direct load control programs are primarily offered to residential or small commercial customers.

Elasticity of Demand

The degree to which consumer demand for a product responds to changes in price, availability or other factors.

Energy Efficiency

Refers to programs that are aimed at reducing the energy used by specific end-use devices and systems, typically without affecting the services provided. These programs reduce overall electricity consumption (reported in megawatt-hours), often, but not always, without explicit consideration for the timing of program-induced savings. Such savings are generally achieved by substituting technologically more advanced equipment to produce the same level of end-use services (e.g. lighting, heating, motor drive) with less electricity. Examples include energy saving appliances and lighting programs, high-efficiency heating, ventilating and air conditioning (HVAC) systems or control modifications, efficient building design, advanced electric motor drives, and heat recovery systems.

Enhanced Customer Service

The ability to offer ultimate customers the choice of bill data, additional rate options such as real time pricing or critical peak pricing, verify an outage or restoration of service following an outage, more information to understand a customer concern over an electric bill, reduce bill estimates when a meter

(Contd.)

read is not available, opening or closing of an account due to customer relocation without requiring a site visit to the meter(s), and/or more accurate bills.

Interruptible/Curtailable Service

Curtailment options integrated into retail tariffs that provide a rate discount or bill credit for agreeing to reduce load during system contingencies. Penalties may be assessed for failure to curtail. In some instances, the demand reduction may be affected by direct action of the System Operator (remote tripping) after notice to the customer in accordance with contractual provisions. For example, demands that can be interrupted to fulfill planning or operating reserve requirements normally should be reported as Interruptible Demand. Interruptible programs have traditionally been offered only to the largest industrial (or commercial) customers. Interruptible Demand as reported here does not include Direct Control Load or price responsive demand response.

Load

The amount of electric power delivered or required at any specific point or points on a system. The requirement originates at the energy-consuming equipment of the consumers.

Load Acting as a Resource

An interruptible program operated by ERCOT in which customers may qualify to provide operating reserves.

Load Forecasting

The estimation of future load requirements for specified intervals for a period of time. The load forecast may provide an estimate of hourly loads for a group of ultimate customers for the next five years, for example.

Real Time Pricing

A retail rate in which the price for electricity typically fluctuates hourly reflecting changes in the wholesale price of electricity. RTP prices are typically known to customers on a day-ahead or hour-ahead basis.

Time-Based Rate

A retail rate in which customers are charged different prices for different times during the day. Examples are time-of-use (TOU) rates, real time pricing (RTP), hourly pricing, and critical peak pricing (CPP).

Time-of-use Rate

A rate with different unit prices for usage during different blocks of time, usually defined for a 24 hour day. TOU rates reflect the average cost of generating and delivering power during those time periods. Daily pricing blocks might include an on-peak, partial-peak, and off-peak price for non-holiday weekdays, with the on-peak price as the highest price, and the off-peak price as the lowest price.

Provided by the European Commission ("European **Smart Grids** technology platform")

Electricity grids of the future are Smart in several ways. Firstly, they allow the customer to take an active role in the supply of electricity. Demand management becomes an indirect source of generation and savings are rewarded. Secondly, the new system offers greater efficiency as links are set up across Europe and beyond to draw on available resources and enable an efficient exchange of energy. In addition, environmental concerns will be addressed, thanks to the exploitation of sustainable energy sources.

Acronyms

AMI Advanced Metering Infrastructure
AMR Automated Meter Reading or Automatic Meter Reading
AMS Advanced Metering Systems
CEER Council of European Energy Regulators
DB Demand Bidding/Buyback
DG Distributed Generation
DLC Direct Load Control
DR Demand Response
DRR Demand Response Resources
DSM Demand-Side Management
EC European Commission
EE Energy Efficiency
ERGEG European Regulators' Group for Electricity and Gas
ESCO Energy Service Company
ETSO European Transmission System Operators
EU European Union
FACTS Flexible AC Transmission Systems
FERC Federal Energy Regulatory Commission (U.S.A.)
ICT Information and Communication Technology
I/C Interruptible/Curtailable service
IEA International Energy Agency
IRP Integrated Resource Plan/Planning
ISO Independent System Operator
LaaR Load acting as a Resource
LM Load Management
LMP Locational Marginal Price/Pricing
MDM Meter Data Management
NERC North American Electric Reliability Council (U.S.A.)
PLC Power Line Communication
PUC Public Utility Commission (U.S.A.)
RES Renewable Energy Source
RF Radio Frequency
RTO Regional Transmission Organization (U.S.A.)
RTP Real-Time Pricing
SCADA Supervisory Control And Data Acquisition
TBR Time-Based Rate
TO Transmission Owner
TOU Time-Of-Use
TSO Transmission System Operator
UCTE Union for the Co-Ordination of Transmission of Electricity
VOLL Value of Lost Load

Jorge Vasconcelos
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