ERRA Licensing and Competition Committee

Issue Paper

REGULATORY ASPECTS OF SMART METERING

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ISSUE PAPER

Regulatory Aspects of Smart Metering

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Submitted by:
David Balmert, Dr. Konstantin Petrov
KEMA International B.V., Utrechtseweg 310, 6812 AR Arnhem, The Netherlands

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<td>AMI</td>
<td>Advanced Metering Infrastructure</td>
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<td>AMR</td>
<td>Automated Meter Reading</td>
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<tr>
<td>CEN</td>
<td>European Committee for Standardization</td>
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<td>CENELEC</td>
<td>European Committee for Electrotechnical Standardization</td>
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<td>CHP</td>
<td>Combined Heat and Power</td>
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<td>DG</td>
<td>Distributed Generation</td>
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<tr>
<td>DSL</td>
<td>Digital Subscriber Line</td>
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<td>DSM</td>
<td>Demand Side Management</td>
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<td>DSO</td>
<td>Distribution System Operator</td>
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<td>EC</td>
<td>European Commission</td>
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<td>EDM</td>
<td>Electronic Data Management</td>
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<td>European Smart Metering Industry Group</td>
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<td>European Telecommunications Standards Institute</td>
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<td>Federal Energy Regulation Commission</td>
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<td>GGP</td>
<td>Guidelines of Good Practice</td>
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<td>General Packet Radio Service</td>
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<td>GSM</td>
<td>Global System for Mobile Communications</td>
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<td>HAN</td>
<td>Home Area Network</td>
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<td>IP</td>
<td>Internet Protocol</td>
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<td>MSP</td>
<td>Metering Service Provider</td>
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<td>MUC</td>
<td>Multi-Utility Communication</td>
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<td>MUC-C</td>
<td>Multi-Utility Communication Controller</td>
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<td>NARUC</td>
<td>National Association of Regulatory Utility Commissioners</td>
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<td>NPV</td>
<td>Net Present Value</td>
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<td>PLC</td>
<td>Power Line Communication</td>
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<td>PV</td>
<td>Photovoltaics</td>
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<tr>
<td>TCP/IP</td>
<td>Transmission Control Protocol/Internet Protocol</td>
</tr>
<tr>
<td>TSO</td>
<td>Transmission System Operator</td>
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<tr>
<td>UK</td>
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<td>United States of America</td>
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<tr>
<td>WAN</td>
<td>Wide Area Network</td>
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1. Introduction

Smart metering and smart grids belong to the ‘hot’ topics which have been attracting more and more attention in recent years, promising to deliver benefits to consumers, producers and network operators alike. However, the exact definition of smart metering is often ambiguous, and it is sometimes unclear what classifies an electricity meter or an electricity grid as smart. It is also debated whether smart metering makes real economic sense, and if so, how it should be promoted.

KEMA was commissioned by NARUC/ERRA to assist ERRA’s Licensing/Competition Committee by providing insight into the key aspects of smart metering, taking a closer look at the fundamental characteristics of smart metering, the potential benefits and barriers of its implementation and the issues related to deploying smart metering in a market environment. With respect to the latter, the objective is also to highlight the major key drivers and success factors for smart metering deployment as well as to look at the role of regulation for a successful smart metering deployment.

This paper relies on KEMA’s experience from several projects as well as knowledge and insights gained in different countries. Practical examples are included throughout the paper, where appropriate. The appendix includes two exemplary dedicated country case studies with a focus on the results of the cost-benefit assessment.

Chapter 2 provides a comprehensive explanation and definition of smart metering and a description of the typical functional requirements and the legal framework in the EU. Chapter 3 assesses the development towards smart grids. Implications of different market models, deployment strategies and the role of regulation are discussed in chapter 4. Chapter 5 takes a closer look at potential barriers to a successful smart metering deployment from different sides. Chapter 6 on costs and benefits of smart metering gives an indication of potential costs and discusses potential benefits for different stakeholders. A high level specification of an economic model for a social cost-benefit analysis is also provided. Chapter 7 provides conclusions.

Gas, heat and water are excluded from a more detailed assessment; the paper’s focus is mainly electricity, although other energy carriers are touched upon where appropriate.
2. **Smart Metering – Definition and Technology**

For the purposes of clarity, it is necessary at the very outset to properly define smart metering to describe the set-up of a smart metering infrastructure. It must be pointed out that there is a significant difference between a smart meter and smart metering. The smart meter is the individual appliance installed at an energy consumer’s house or facility, primarily metering the consumer’s energy consumption. Smart metering is an actual application of smart meters on a larger scale, i.e. the application of a general principle rather than an individual appliance. However, when looking at smart metering pilot projects or national smart metering programs, there are sometimes differences to be found in the definition of smart metering. Additionally terms like Automated Meter Reading (AMR) and Advanced Metering Infrastructure (AMI) can often be seen, especially in the USA, whereas in the EU often the rather vague term “intelligent metering systems” is used. The following section provides a comprehensive definition of smart metering, which has been developed and fine-tuned in KEMA’s previous projects with several stakeholders and in various countries but is also in line with definitions applied by other institutions, for instance the European Commission or the European Smart Metering Alliance (ESMA). In this section a description of a smart metering infrastructure is also included, as well as a discussion of different technological approaches and additional functionalities, a description of consumer feedback on smart metering as one of the major mechanisms to achieve energy savings and a description of the most relevant legal framework in the European Union.

2.1 **Definition of Smart Metering**

Whereas in some cases simple remote meter reading – corresponding with AMR – is seen as smart metering, in most cases the functionalities required for smart metering are far more extensive. The above mentioned term AMI is defined by the United States Federal Energy Regulation Commission (FERC) as “the communications hardware and software and associated system software that creates a network between advanced meters and utility business systems and which allows collection and distribution of information to customers and other parties, such as competitive retail providers, in addition to providing information to the utility itself.” AMI is often used synonymously with smart metering; however, during recent years the possibility to use the communication links in both directions has become one of the more important functionalities, thus enabling home automation, remote (dis-)connection, remote firmware updates and additional services.

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1 Federal Energy Regulatory Commission Survey on Demand Response, Time-Based Rate Programs/Tariffs and Advanced Metering Infrastructure – Glossary, 2008, p.1
The European Commission’s interpretative note on Directive 2009/72/EC for example describes “the ability to provide bi-directional communication between the consumer and the supplier/operator” and to “promote services that facilitate energy efficiency within the home” as key requirements of smart metering. A comprehensive overview of different definitions applied in the EU Member States is included in the ERGEG status review from October 2009. The ERGEG report concludes that the bidirectional communication capability in particular is a crucial key function of a smart meter.

To provide clarity on the term smart metering, KEMA suggests the following definition:

Smart Metering is
- Automatic reading, processing and transmission of metering data,
- Possibility of bidirectional data communication in real-time (or with only a small time lag),
- Support of additional services and applications, e.g. home automation, remote (dis-) connection of supply or load limitation, and
- Remote update of meter firmware to enable new services, communication protocols, etc.

It is also important to point out that the implementation of smart metering requires a complete smart metering infrastructure consisting of smart meters themselves, a communication infrastructure linking the smart meter at the consumer’s site with the meter operator, supplier or network operator, and a data management infrastructure at the back end of the meter operator, supplier or network operator linked to accounting and invoicing systems.

Typical functional requirements for smart metering can be observed in existing roll-outs and often include the following (although apart from the key requirements presented in the above definition, not all functionalities need to be included when deploying smart metering):
- Measurement of energy consumption and injection (if applicable)
- Remote reading of meter data, either regularly submitting consumption data (e.g. as load curve) or submitting meter readings on demand
- Submitting (and displaying) information on tariffs, historic consumption, comparison values, etc. to the meter
- Storage of meter readings and/or load curve (e.g. until next regular submission or in case communication is interrupted)
- Remote connection/disconnection and load limitation
- Remote firmware upgrades, programming or addition of new functions to the meter

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3 ERGEG, Status Review on Regulatory Aspects of Smart Metering (Electricity and Gas) as of May 2009, Ref: E09-RMF-17-03, Brussels, 19 October 2009
• Transmitting on demand of diagnosis of power quality/condition and voltage level
• Automatic transmission of fraud alarm
• Communication with other meters or a separate (multi utility) communication device and household appliances
• Prepayment function, so that the meter can be used as a budget meter
• Display on the meter itself and transmission of meter data to an external display, e.g. an in-home display

A list of functionalities as recommended by ERGEG can be found in chapter 2.4. The set of required functions is clearly (at least partly) dependent on local circumstances and above all on the objectives of the planned smart metering roll-out. If, for example, remote meter reading to provide data for monthly invoices is the driver (as was the case in Sweden), all functions regarding real-time consumer feedback, remote (dis-) connection, load limiting, home automation, etc. may be dispensable, although the Swedish approach might — strictly speaking — not meet the requirements of the above definition. In another case, in Italy, the main driver for the national smart metering roll-out was the reduction of fraud. This objective renders direct consumer feedback and home automation obsolete. European legislation on smart metering is, however, driven by the objective of achieving energy savings with smart metering. Additional benefits from the reduction of commercial losses (i.e. theft of electricity) may also be expected in some of the ERRA countries. In this case the consumer feedback functionalities are crucial for success. In the United States of America (USA) smart metering installation is mainly driven by generation capacity constraints and thus targeted on reducing peak load. In this case consumer feedback is crucial as well. However, the significant difference in the objectives either to reduce the overall energy consumption or only to shift consumption from peak to non-peak times should be noted.

In order to ensure an efficient approach in line with the national objectives for smart metering deployment, minimal functional requirements need to be set. Certain functions are crucial to enable new services to maximize potential benefits. However, if functional requirements are set too high, the resulting benefits may be achieved at great cost.

Smart metering is often perceived to be an electricity topic. Due to the properties and consumption patterns of electricity, this is certainly the most promising area of application for smart metering. However, it can also be relevant for other network industries such as gas, water and district heating. Successful smart metering deployment for other energy carriers is dependent on the market structure. It is easier to handle with higher synergies to be gained if, for example, electricity and gas are supplied by the same company or if metering for both belongs to the same metering service provider.
2.2 Description of a Smart Metering Infrastructure

A smart metering infrastructure in line with the above definition basically consists of the following elements:

- Metering device and associated devices
- Communication and data processing infrastructure
- In-home energy use display

![Smart Metering Infrastructure Diagram](image)

**Figure 1: Smart metering infrastructure**

The above figure shows an exemplary fully fledged smart metering infrastructure. In practice some of the depicted elements are not a mandatory part of smart metering, for instance the so-called Smart Home Unit, controlling household appliances based on actual load and price information.

2.2.1 The Meter and Associated Devices

When implementing a smart metering infrastructure, traditional meters, e.g. electromechanical induction electricity meters and bellow-type gas meters in the residential sector, are replaced with modern electronic meters with interfaces to communicate with other elements of the smart metering infrastructure. Besides improving meter accuracy, new generation meters are accessible electronically and meter readings are shown on digital displays. Moreover, by using an integrated or modular attached communication module, meter readings can be transmitted directly to the consumer, using the home area network (HAN), and the metering operator, the supplier and/or the network operator, using the wide area network (WAN).
To enable the required functionalities for smart metering, the new meters need to be able to submit meter data as well as to receive and process electronic data, e.g. tariff changes, commands for a remote (dis-)connection, firmware updates, etc.

If smart metering deployment is targeted not only to electricity meters, different meters can be integrated into a so-called Multi Utility Communication (MUC) environment, sharing the joint communication infrastructure and thus preventing costly redundancy. In a MUC environment the communication module is either completely separated (Multi Utility Communication-Controller, MUC-C) with different meters for electricity, gas, etc. connected to it, or one of the meters, for instance the electricity meter, contains the communication module with interfaces enabling other meters to be connected to it and share the communication infrastructure. The first option based on a modular set-up allows for easy exchange of individual components.
2.2.2 Communication and Data Processing Infrastructure

A communication infrastructure is needed to connect the metering devices to the customer, i.e. to the customer’s energy use display, and also the metering devices to the meter control center and electronic data management (EDM) system. The data flow to the consumer can either be directly through the home area network (HAN), using communication technologies such as wireless/wired M-Bus, ZigBee or power line communication (PLC). Optionally, data can be transmitted to the consumer only indirectly through the EDM, providing data on web portals, per short message service or only the invoice. If real-time provision of meter data to the consumer is intended, the direct transmission to consumers is preferable. Thus the transmission interval to the back-end can be chosen depending on the needs, e.g. only daily, and possibly sensitive real-time data remains in the consumer’s sphere.

For data transmission to the EDM at the network operator, metering operator or supplier through the wide area network (WAN), three technologies are generally used: (1) power line communication (PLC), (2) GSM/GPRS based mobile phone technology or (3) broadband internet connections (DSL).

All of these technologies have pros and cons; in some cases a combination of two technologies is required. The basic decision, based on local circumstances and deployment strategy, is that data is transmitted directly from the consumer’s site to the EDM or bundled locally with a so-called data concentrator and forwarded to the EDM from there.
Data concentrators are only recommended in more densely populated areas, where there is a denser roll-out of smart meters which can be connected to data concentrators. Normally metering devices are connected to data concentrators with PLC, with up to several hundred meters per data concentrator. Data concentrators not only bundle meter data, but can also check, process and store meter data, passing them on to a data center at a higher level. As the range of PLC is limited, it can only be used for local connections in the HAN or between HAN and data concentrator in the neighborhood (e.g. in a transformer station or low voltage substation).

PLC is the collective name for techniques which enable telecommunication using the electricity distribution network as a communication channel. A common application of PLC is the reading of metering data from energy consumers. For this purpose, equipment is installed in the consumer’s electricity meter which can transfer the recorded metering data to the data concentrator.

GSM (Global System for Mobile Communications) is the designation for a standard of digital mobile telephony. GSM is regarded as the second generation of mobile telephony (2G) and is the most used mobile telephony standard in the world. GPRS stands for ‘General Packet Radio Service’, which is an extension technology to the existing GSM network. Mobile data can be sent and received more efficiently, rapidly and cheaply using this new technology. GPRS users are always online. This means that they have a constant connection with the internet or company network and therefore only need to set up the connection once to be online for the whole day. For this, they do not pay for the time they are logged on, but are billed for the quantity of data they download or send. Technically speaking, the user also only keeps the line busy at times when it is actually being used. This allows for a better use of capacity and enables larger volumes of data to be exchanged at the same time. Metering data can be sent to or requisitioned from a data center at a higher level on a regular basis (daily or monthly).

GSM/GPRS communication exhibits relatively high investment and operation costs per single communication unit, but can be operated without requiring substantial infrastructure. GSM/GPRS is thus deployed either for direct connections between meter devices and EDM, if the population or smart metering density does not allow for usage of data concentrators, or to connect data concentrators to the EDM.

Alternatively, the consumer’s broadband internet connection (DSL) can be used to transmit meter data directly to the EDM. Modern electricity meters have TCP/IP output, in principle allowing direct access to the worldwide internet. The metering data is then sent via the Internet Protocol (IP). This does however require software inside the meter, to allow communication to take place properly.

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4 For example for fraud detection a check could be made to determine if the sum of supplied energy (sum of all individual meter readings) equals the sum of consumed energy (in total, measured at a substation).

5 I.e. the metering provider does not need substantial infrastructure; nevertheless a mobile communication network is certainly required.
The communication links are bi-directional in principle, which is to say that information can be exchanged in two directions (to and from the meter). If this solution is selected, no further hardware is required beyond the consumer’s modem. What is required, however, is some extra functionality within the meter to be able to communicate at IP level. Although this solution is dependent on the existence of such an infrastructure and comes with the downside that this infrastructure is under control of the consumer itself, it is comparably cheap.

Cost indications for different communication technologies are included in chapter 6.2.

### 2.2.3 In-Home Display

The third element of the smart metering infrastructure is the interface with the consumer, giving the direct feedback on consumption and associated costs. Depending on the type of feedback chosen, the in-home display is not seen as a mandatory part of a smart metering infrastructure in all cases. Please see the following section for a discussion of different types of feedback. The in-home display can be either a dedicated display, as depicted in Figure 4, or a web-based portal accessible from the consumer’s computer or for instance by a modern smartphone. Either the connection with the smart meter is made directly, using typical HAN communication channels, or it can be routed through the data center and then provided via WAN. If a dedicated display is used, the first case is the more likely; a web-based internet portal uses the latter of course.

### 2.3 Feedback to Consumers on their Energy Use

One of the main objectives behind smart metering deployment is to achieve substantial energy savings and thus reduce society’s greenhouse gas emissions. Basically these energy savings can be achieved either by increased efficiency or sufficiency. Increased efficiency means that the same benefit is generated from less energy used, e.g. due to improved thermal insulation of residential buildings. Sufficiency is the achievement of energy savings due to changes in the consumer’s behavior which also lead to decreased comfort, e.g. by lowering the average room temperature. Whereas energy savings based on higher efficiency in general require investments, sufficiency comes at no monetary cost.

The most important driver to achieve energy savings is to improve the feedback on energy consumption and costs given to the consumer. Smart metering creates the possibility to provide the consumer with accurate information on actual energy consumption, actual time of use and energy costs. The information can be given for instance in real-time, e.g. on in-house displays or web portals, as a daily summary, or by providing a monthly invoice based on real meter data. Traditionally the feedback on consumption is based on monthly or annual meter readings, in some cases meters
are even only read every two years. Without effective feedback to consumers on their energy consumption, smart metering may fail to achieve sufficient energy savings which are one of the major sources of benefits.

Several forms of feedback can be distinguished. Those most relevant for smart metering are:

- **Direct feedback**, e.g. through in-house energy consumption displays or web-based information portals with real-time information
- **Indirect feedback**, e.g. through more frequent invoicing based on actual meter readings, enhanced with comparison values from peer groups, energy savings advice or information on energy savings achieved so far.

Direct feedback is characterized by simple access to the consumption data, e.g. through an in-house display, as depicted on the right side of the above figure, or a web-based portal which provides real-time information. Direct feedback enables the consumer to monitor energy consumption constantly and to take measures to reduce energy consumption if deemed appropriate and feasible. Using the bi-directional communication, the display can, besides the actual meter readings, also show information retrieved from the outside, e.g. prices, weather, system state, etc. For direct feedback, e.g. real-time information provided to the consumer, it is not necessary to submit real-time information to the outside. Very simple systems measuring only the amount of electricity consumed and sending

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6 This can be the case where meters are typically read by the consumer itself and then submitted to the utility. If the consumer fails to submit actual meter data the annual invoice is then based on estimated consumption. However, in countries where this is generally allowed, usually regulations apply stipulating how often manual meter reading by the utility has to take place, e.g. every two years.

7 A very comprehensive overview of different types of feedback and potential impact to be achieved is for instance given by Darby, Sarah, The Effectiveness of Feedback on Energy Consumption, Oxford, 2006
this information to an in-house display can be easily fixed to the traditional electricity meter without any other smart metering functionalities.\textsuperscript{8}

Indirect feedback is characterized by some kind of processing of the meter data by the meter or network operator or the supplier before the information is provided to the consumer. The periodically sent invoice is a typical example of indirect feedback. Smart metering can improve this indirect feedback by sending accurate invoices based on actual consumption data more frequently and by enhancing these with additional information, enabling and motivating the consumer to take action to decrease energy consumption, as shown on the left side of the above figure.\textsuperscript{9}

Whereas direct feedback seems to provide for faster and greater energy savings, indirect feedback in the form of more regular and comprehensive invoices seems to create more sustainable energy saving effects. In order to maximize energy savings, it appears reasonable to combine both feedback mechanisms.

2.4 EU Legal Framework and Requirements

The EU wide legal framework for smart metering is mainly set by the Directives on the internal markets for electricity and gas (2009/72/EC & 2009/73/EC, the so-called Third Package) and the Directive 2006/32/EC on energy end-use efficiency and energy services. Directive 2004/22/EC on measuring instruments contains relevant (mostly) technical provisions for metering devices, also applicable for smart metering. Other Directives encouraging (but not requiring) advanced or intelligent metering systems in order to promote energy savings and demand response are Directives 2005/89/EC and 2010/31/EC.

Directive 2006/32/EC can be seen as the first Directive requiring smart metering deployment in EU Member States, although the term ‘smart meter’ is not used. Instead Art. 13 requires that “final customers are provided with competitively priced individual meters that accurately reflect the final customer’s actual energy consumption and that provide information on actual time of use”. However, the requirement is subject to technical feasibility, financial viability and proportionability to potential energy savings. Additionally, the same article includes provisions that require invoicing to be based on actual

\textsuperscript{8} Such a system was for example tested in pilot study in Ontario, c.f. Mountain, Dean, The impact of real-time feedback on residential electricity consumption: the Hydro One pilot, Ontario, 2006

\textsuperscript{9} The isolated impact of improved billing was for example tested in Norwegian project, c.f. Wilhite, Harold, Hoivik, Asbjorn, Olsen, Johan-Gemre, Advances in the use of consumption feedback information in energy billing: the experiences of a Norwegian energy utility, 1999
consumption and that it is also “performed frequently enough to enable customers to regulate their own energy consumption”.10

However, Directive 2006/32/EC was transferred into national legislation quite differently and only in a few Member States led to a national smart metering deployment, e.g. Sweden. The requirement for smart metering is finally stipulated in the Third Package for further liberalization of the internal markets for electricity and gas. Annex I of both Directives (2009/72/EC for electricity and 2009/73/EC for gas) contains provisions to promote smart metering requiring Member States to “ensure the implementation of intelligent metering systems […] The implementation of those metering systems may be subject to an economic assessment of all the long-term costs and benefits to the market and the individual customer or which form of intelligent metering is economically reasonable and cost-effective and which timeframe is feasible for their distribution. Such assessment shall take place by 3 September 2012.” For gas, only the preparation of a timetable for smart metering implementation is required, subject to economic assessment. For electricity, a time horizon of ten years is set for the timetable. Furthermore, if roll-out is assessed positively, Member States are required to ensure that 80% of consumers are equipped with intelligent metering systems by 2020.11

Shortly before passing the Third Package, the European Commission had already mandated European standardization organizations to develop an open architecture hardware and software standard for smart metering systems enabling interoperability of meters.12

Reacting to the requirements of the Third Package regarding smart metering, ERGEG published a consultation paper in June 2010 containing “Draft Guidelines of Good Practice on Regulatory Aspects of Smart Metering for Electricity and Gas”. The Guidelines of Good Practice (GGP) define the minimum and optional services which smart metering should provide to electricity and gas customers and make suggestions on the conduction of economic assessments, the roll-out and on data security.13

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<th>Electricity</th>
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<td>Minimum cus-</td>
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<td>1. Information on actual consumption, on a monthly basis</td>
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12 European Commission, Standardisation mandate to CEN, CENELEC and ETSI in the field of measuring instruments for the development of an open architecture for utility meters involving communication protocols enabling interoperability, M/441 EN, Brussels, 12 March 2009
13 ERGEG, Public Consultation Paper on Draft Guidelines of Good Practice on Regulatory Aspects of Smart Metering for Electricity and Gas, Ref: E10-RMF-23-03, Brussels, 10 June 2010
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<th>2. Accurate metering data to relevant market actors when switching supplier or moving</th>
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<td>5. Power capacity reduction/increase</td>
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<td>6. Activation and de-activation of supply</td>
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<td>7. Only one meter for those that both generate and consume electricity</td>
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<td>8. Access on customer demand to information on consumption data</td>
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<td><strong>Optional services</strong></td>
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<td>11. Interface with the home</td>
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<td>12. Information on voltage quality</td>
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<td>13. Information on continuity of supply</td>
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<td><strong>Costs and benefits</strong></td>
<td>14. When making a cost benefit analysis, an extensive value chain should be used</td>
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<td><strong>Roll-out</strong></td>
<td>15. All customers should benefit from smart metering</td>
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<td>Minimum customer services</td>
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<td>28. No discrimination when rolling out smart meters</td>
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<td>Data security &amp; integrity</td>
<td>29. Customer control of metering data</td>
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**Table 1: Draft GGP on regulatory aspects of smart metering. Source: ERGEG**

### 3. Smart Metering and Smart Grids

#### 3.1 Definition of Smart Grids

The smart grid concept is a vision of the future electricity network. It does not have the same relevance for gas or heat as for electricity, although in some cases it is extended for example to gas. Traditionally, when controlling electricity networks, load was considered as given and generation was designed and operated to match the load, predominantly based on easily controllable large central power stations. Electricity was flowing in one direction from high to low voltage level of the
electricity network. With a changing generation mix including high shares of intermittent (decentralized) generation and changing load patterns, for instance due to plug-in electric vehicles and heat pumps, a paradigm shift is needed. For an efficient and sustainable future electricity supply system, it is necessary to also influence load – as the degree of freedom to control generation decreases – and to facilitate bidirectional electricity flows.

A smart grid is a combination of modern information and communication technologies with state-of-the-art network assets to enable the power grid to transport energy and information in a bidirectional way, thus facilitating consumer energy savings, demand response and subsequently integrating high shares of (mostly intermittent) renewable energy sources, distributed generation (DG) and electric vehicles (enabling the necessary load management). The smart grid is thus rather a set of functionalities than a set of individual appliances.

### 3.2 Description of Smart Grid Infrastructure

As mentioned above, the smart grid is mainly characterized by the abilities and functions it provides and not necessarily by the set of individual appliances of which it is comprised.

The smart grid is comprised of or characterized by:

- Smart metering infrastructure encompassing all consumers
- Demand response schemes and dynamic pricing
- Active consumer participation in energy markets
- High penetration of often intermittent generation sources, such as distributed generation (DG) and renewable power generation (wind, PV, water, biomass, ...)
- Self-healing ability and islanding in case of network failures and high resistance against attacks on the system
- Improved asset management and real-time equipment and power quality monitoring
- Significant energy storage capacities
Figure 5: Smart grid design. Source: European Commission, DG Research

A smart grid is based on smart metering providing the required data on load and DG, but extends the approach further by combining metering and meter data with other information on network status, generation, real time price information and active communication. As a result, it is possible to generate signals enabling (automatic) demand and supply management according to the specific operating conditions.

The metering hardware needs to be combined with HAN and WAN communication networks, home automation, commercial building and industrial energy management and control systems and intelligent (automated) control of distribution networks. The smart grid thus combines residential, commercial and industrial load, distributed and central generation as well as generation from renewable power sources, e.g. micro CHP and PV units in households, larger block heating stations, central fossil power plants, along with large scale renewable generation from wind with future storage solutions. It combines remotely manageable generation and load to virtual power plants providing ancillary and reserve services and enabling consumers to take part in energy markets. Quality of supply can be closely monitored and improved fault location and self-healing ability due to improved (automated) distribution network management will lead to decreased outage times and also to improved voltage and frequency control.

Smart grids are a future vision; the commercial application is realized yet. It is possible that smart meters which are currently in use or are actually deployed right now may need to be replaced before the end of their lifetime, as some of the functionalities required for a smart grid have not yet
been included. However, smart metering deployment – and especially developing a communication infrastructure – will be a major step towards building the smart grid.

4. Market Models and Regulation for Metering

4.1 Metering Market Models

In this section different models for organizing the metering sector are described and discussed. In most countries, metering is traditionally part of the distribution system operator’s (DSO) business activities; especially in the pre-liberalization era, when the provision of energy services was in most cases in the hands of a vertically integrated utility. This utility was often municipally owned and in many cases provided electricity, gas, water, district heat and even public transport together. The consumer thus had a single point of contact for network connection, supply, metering and invoicing. Nowadays DSO activities in EU Member States are subject to liberalization and unbundling provisions, although only seldom was ownership unbundling at distribution level made mandatory (e.g. for electricity in The Netherlands).

For electricity metering two types of schemes can be found in the European Union. In most countries the metering sector remains regulated, with one or more designated entities being responsible for metering, subject to regulatory oversight. In most of these cases metering simply remains part of the regulated DSO functions, as for instance in the USA, with vertically integrated utilities being responsible within their service areas. However, in a few countries metering was unbundled from the other DSO activities although it remained a regulated monopoly segment. In some countries the metering sector was even liberalized, such as in Germany and the Netherlands, hoping for instance for competition between metering service providers to drive down metering costs. So far however, it seems that no independent metering service provider has been seen to rise in a competitive environment against DSOs. What happens, however, is that suppliers take up the metering role, trying to strengthen customer relationships by offering for example smart meters. In relation to smart metering roll-out, the model of a monopoly metering service provider at regional or national level is under discussion, as was/is for example the case in the United Kingdom (UK) or in Hungary.

14 Although in the Netherlands the metering market model has shifted back to a regulated market model again, due, amongst other things, to the smart metering deployment strategy.

15 In the UK such an approach was discussed under the name Regional Franchise Model. The final roll-out decision however put the responsibility on suppliers.
In the majority of the ERRA countries metering remains part of the regulated DSO functions, although sometimes consumers and suppliers are also allowed to own meters. The costs of meters are recovered via the regulated network charges, and investments in metering equipment are subject to regulatory approval. Although the regulatory regimes vary from country to country, all regulatory regimes known to us apply an ex-ante regulatory review and explicit approval of investments before inclusion of costs in the allowed revenue.

4.1.1 Basic Metering Market Models

All things considered, it seems that three basic metering market models could be of major relevance for the ERRA members:

1. The DSO owns and operates the metering infrastructure and performs metering services
2. An independent Metering Service Provider (MSP) performs metering services. The ownership and operative responsibility for the metering infrastructure could lie with the MSP ('fat' MSP) or with the DSO ('lean' MSP).
3. The metering function is performed by the supplier in a liberalized metering environment.

Of course these are exemplary basic models; practical application might see plenty of variations. The following major functions as part of the metering business can be distinguished:

- Ownership of metering infrastructure
- Planning of metering deployment
- Installation and maintenance of metering infrastructure
- Operation of metering infrastructure
- Meter reading
- Data collection and processing
- Providing data to customers, suppliers and other eligible stakeholders
4.1.2 Pros and Cons of Metering Market Models

The competitive electricity market requires the unbundling of activities. In addition to the classical unbundling between supply and network, the metering business can also be separated. This is of special importance if the metering sector is opened for competition.

In the case of the first model, all metering functions remain within the DSO, no unbundling of the metering business takes place. This is traditionally the case. A DSO led smart metering deployment would thus fit smoothly into existing industry structures. Moreover, as smart metering might be seen as the natural precursor of the smart grid, it makes great sense for the DSO to take up responsibility for smart metering.

From the regulatory economic point of view, i.e. considering the potential for discriminative behavior, this is uncritical if the DSO is separated from the supply side. However, if DSOs are integrated with the supply side, the arguments which would support a separate metering entity are even stronger in favor of separating the whole network business from the supply side. Subsequently separating the metering part from an otherwise completely vertically integrated utility would make little sense (except for the reasons discussed in connection with a liberalized market or a multi-utility approach below).

In a vertically integrated utility, leaving smart metering with the DSO is the most significant option in terms of efficiency and effectiveness. However, in most countries, liberalization of the final consumer’s market has either already been accomplished or will be in the near future. Even if the DSO remains the default supplier, in many cases he may lose a customer’s supply contract to another supplier. The DSO would need to establish data processing routines, forwarding the meter data for invoicing purposes, etc. to the new supplier. Further communication interfaces would also be required, for example to transmit price data or control commands for demand response schemes from the supplier to the customer. The supplier would submit the required data to the DSO’s metering control center and the DSO would need to forward the data to the customer. Although this might work in theory, the practical application might be complicated and could even be a potential source for abusive and discriminatory behavior of the DSO against competitors. One possible solution would be to allocate metering responsibility to the supplier, in accordance with the supply contract.

However, it does not make general sense to shift meter operation together with a supply change (supplier model). Meter operation does need on-site resources, such as personnel for meter installation. It is also strongly dependent on the technological choices made. If, for example, the smart metering infrastructure is based on PLC, meter operation cannot be shifted easily from the DSO to the supplier; this would only be feasible using GSM/GPRS or DSL communication. Moreover, even with
hard and software standards widely established, it is possible that the new supplier would require a
different meter to be installed, resulting in inefficiently high transaction costs and stranded invest-
ment. A supplier’s responsibility would thus pose a barrier to changing the supplier and subsequently
hinder competition.

On the other hand, the DSO model would be complicated in a multi-utility approach. The business
case for smart metering in the gas or district heating sector is seldom positive, but it can be signifi-
cantly improved using a combined and integrated approach, sharing a joint communication infrastruc-
ture. In some cases a single DSO is responsible for electricity, gas and district heat supply; however,
different DSOs often deliver different energy carriers. In a multi-utility environment the smart me-
tering deployment would be led by one of the DSOs, most probably the electricity DSO. To inte-
grate the other energy carriers, separate metering devices and an additional multi-utility communica-
tion controller (either as a separate device or integrated into the electricity meter) would be
needed. The leading DSO would require communication interfaces to communicate with the other
DSOs and probably also with additional suppliers, providing data to all authorized stakeholders and
also forwarding data back to the consumer. Such a set-up would not only require significant coordi-
nation between all stakeholders, but moreover costs would need to be distributed among all parties.
Given the fact that different DSOs (if also responsible for supply) may in some cases be in competi-
tion with each other, e.g. for space heating/heat pumps, the leading role of a single DSO could be a
potential source for abusive and discriminatory behavior against competitors. Most of these argu-
ments are even more relevant in the supplier led smart metering roll-out.

The fundamentally different approach would be to unbundle the metering business from network
functions. In that case a separate entity would be required. This entity could then act as independent,
monopolized, regulated, regional or national metering service provider (MSP), fulfilling all or most of
the above mentioned functions. Ownership of the metering infrastructure could be with either the
MSP or with the DSO. It seems to make sense however, especially in relation to the smart grid de-
velopment, to leave the ownership with the DSO (and thus also installation and maintenance). In this
case the MSP would be responsible for meter reading, data processing and data management (‘lean’
MSP). Authorized stakeholders would have role-based access to all the relevant data, i.e. the gas
supplier would only have the individual gas consumption data relevant for billing purposes, whereas
the electricity DSO would only have access to relevant network data, e.g. power quality and outage
data or accumulated consumption data.

The supplier model seems to generate a high potential for inefficiencies, such as high coordination
costs and stranded investments if the supplier is changed. A multi-utility approach seems barely imagi-
nable with the supplier model.

In order to promote smart metering, both the DSO and the MSP models may have their advantages.
The DSO model seems especially suited to a fast track smart metering roll-out focused on electric-
ity. In this case the DSO would be the natural stakeholder responsible for smart metering, although in the case of retail market opening, processes and communication interfaces between the DSO and suppliers would need to be established and safeguards would be required to prevent discriminatory behavior. The MSP model seems to be better suited to ensuring the successful implementation of a multi-utility approach. However, as such an entity would need to be newly founded; deployment of the MSP model would require more time.

4.1.3 Metering Infrastructure Ownership

In the DSO model, ownership of the metering infrastructure is generally with the DSO. In a multi-utility environment a decision needs to be made concerning which assets belong to the respective DSOs. One feasible approach would be that the metering infrastructure including the multi-utility communication controller belongs to the leading (electricity) DSO, whereas the other DSOs own only ‘their’ metering device each. The capital costs for the metering infrastructure would then be partly rolled-into the service fee charged by the leading DSO to either the other DSOs, the suppliers or the customer itself. This would depend on the concrete set-up of contractual relations.

In the MSP model, meter ownership could be either with the MSP (‘fat’ MSP) or with the DSO (‘lean’ MSP). As metering is traditionally part of the DSO and also strongly linked to the DSO’s network functions, the necessary personnel and technical resources are most likely available at the DSO. If metering were part of a newly founded MSP, such resources would need to be relocated to the MSP and contractual arrangements would also be required for use of the DSO’s assets (e.g. for PLC). Such an undertaking appears to be time consuming and costly and depending on existing market structures, may also require the DSO’s voluntary participation. To avoid such problems, it would seem viable for metering infrastructure ownership, installation and maintenance to remain with the DSO, whereas the responsibility for meter readings, data processing and management and provision of data to all authorized stakeholders would belong solely to the MSP.

Apart from ownership of the major parts of the metering infrastructure, the individual metering devices in certain countries can be owned by other parties, e.g. the consumers, suppliers or energy saving consultants. This is for instance the case in Poland, Romania and Slovenia. Such a constellation could be a barrier to smart metering deployment, as a meter owning consumer might be hesitant to invest in a new meter, thus bearing the cost of stranded investment. However, such problems may by curbed by proper incentive schemes to promote investment into smart meters and by sound technological standards guaranteeing interoperability to prevent stranded investment if consumers change their supplier.

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16 At least if the DSO is still part of an integrated utility, although in that case such safeguards are always necessary.
4.2 Deployment Strategies

Besides the metering market model, one of the key questions when devising the smart metering deployment strategy is the decision on the speed of smart metering roll-out. The timeframe for a smart metering roll-out – if full-scale national roll-out is the objective – seriously affects costs and benefits, due for instance to the

- necessity to operate two systems in parallel as long as old meters are in existence,
- peaking demand for a qualified labor force,
- metering and communications hardware and installation equipment and
- stranded investments if old meters are replaced before reaching the end of their economic lifetime.

The benefit from smart metering can be roughly distinguished into benefits achieved with every individual meter, e.g. reduction of final energy consumption, and benefits stemming from a generally established smart metering infrastructure. Whereas benefits in the first case can be generated from installing the first smart meter onwards and can be quantified as a multiplication of average benefits per meter/household and number of meters installed, the latter might only be realized after reaching a certain threshold of installed meters. This needs to be considered when devising the deployment strategy.

The smart metering deployment strategy should be based on the objectives targeted, the existing market structure and infrastructure and the timeframe by which smart metering should reach full coverage. The most extreme approaches relating to the timeframe could thus be a fully voluntary roll-out or a short-term mandatory roll-out. Other decisions have to be made regarding the technological choices and the accompanying measures, such as consumer awareness programs.

4.2.1 Voluntary Smart Metering Roll-Out

A voluntary roll-out would be based on the individual decisions of metering providers (regardless of who is responsible for metering) to offer smart meters to customers and to build up a smart metering infrastructure. Significant investment would be needed for the communication and data processing infrastructure required. A roll-out decision would thus be based on an individual positive business case, e.g. for the DSO or the supplier. Depending on the approach decided on by the metering provider, smart meter installation might also need the individual decision of a final customer to adopt smart metering. A DSO could, for instance, decide to roll-out smart meters to all consumers connected to its grid but it could also offer the smart metering service as one service option besides others with traditional meters. The latter would probably be the slowest approach, with at first only so-called innovators and early adopters among the consumers to use a smart meter.
Even with a mandatory roll-out by a DSO, the time frame would be dependent on the approach chosen - for instance replacing only those meters which are due to be replaced anyway with smart meters, or a more progressive roll-out. The major key factors have to be assessed. Assuming (for the sake of argument) that the roll-out is led by the DSO, after starting the smart metering roll-out, the DSO would need two separate systems for collecting and processing meter data. Two different invoicing schemes would also probably be required and technical personnel would need to deal with traditional and new meters. This is in any case costly as long as old and new metering infrastructures co-exist.

On the other hand, depending on the age pattern of the existing metering infrastructure, a fast-paced roll-out of smart metering could result in significant stranded investment, in which case a more gradual approach might be advantageous. A fast-paced roll-out would also result in peaking demand for resources, such as a qualified labor force. In any case, with a voluntary deployment strategy the trade-off and the decision on roll-out speed would be subject to internal optimization of the party deciding on the roll-out in the first place.

A voluntary deployment could be observed at the beginning in Italy, where Enel (covering 85% of low-voltage customers) started to deploy smart metering for electricity in 2001 and full coverage is expected by 2011. Important reasons for Enel's decision were the expected savings or revenues in the areas of purchasing and logistics, field operations, customer services and revenue protection. Fraud (i.e. theft of electricity) in particular was a very widespread problem in Italy. The roll-out decision by Enel was made before the energy market was liberalized, although the Italian regulator took a mandatory roll-out decision in 2007, requiring 95% of all low-voltage customers to be equipped with smart meters by 2012 and also setting minimum functional requirements.

In Sweden, where the roll-out is almost completed, the decision was made by the DSOs, although they were being pushed by the requirement for monthly meter reading. Based on this requirement however, the net benefit was assessed as positive by the DSOs. It should be noted that this requirement for monthly meter reading which led to a smart metering deployment in Sweden might not have the same effect in other countries. This is highly dependent on the existing conditions, e.g. geography, labor costs, traditional approach, etc.

In the USA the decision for smart metering deployment is typically triggered by the utility, thus making it also a voluntary approach. However, in most states the regulator’s approval is required for tariff adjustments and cost recovery plans. Based on this approach, the projection was to have 52 million smart electricity meters installed by the end of 2010.

17 In some cases, though, the rolled out meters fulfill only simpler remote meter reading functionalities and might not be considered as smart metering (even when the meter device itself could be considered as a smart meter).
4.2.2 Mandatory Smart Metering Roll-Out

An alternative approach would be a mandatory national roll-out in a given timeframe, as is implied by the Directives 2009/72/EC for electricity, if a cost-benefit analysis shows an overall positive net benefit. In this case the roll-out would have to be completed ten years after the positive assessment, with 80% market penetration by 2020. The Directive itself actually does not demand that Member States implement a mandatory roll-out scheme, however given the very ambitious timeframe, it is doubtful whether a voluntary roll-out approach would be feasible.

In a mandatory roll-out the metering provider (DSO, MSP or supplier) would be obliged to build up a smart metering infrastructure and to replace existing meters with smart meters. In this case the roll-out decision would not be based on the economic assessment of an individual player; instead a social cost-benefit analysis would be required, assessing costs and benefits for society as a whole. If the overall net benefit is assessed as positive, a mandatory roll-out would follow. Generally, costs and benefits are dependent on the status quo, the targeted objectives and the chosen approach. Pilot projects can be conducted to improve quantification of costs and benefits and also to test available technology.

Up to now several pilot projects have been carried out in most countries. Given the sometimes very specific circumstances and needs in a country, results of pilot projects in other countries should be carefully assessed before transferring them to another country. It seems advisable to support a social cost-benefit analysis with results from a country’s own pilot projects. Experience shows that feasibility for example can be assessed very easily in a pilot project. Quantifying benefits, e.g. from energy savings or load shifting is much more complex, as pilot projects have to comply with statistical minimum requirements and must have a sufficient timeframe to allow assessment of the long-term development of effects.

The aforementioned problems in a fast-paced roll-out, i.e. the possible high costs due to stranded investments and the peaking demand for resources would also be present in a national roll-out. In fact these problems would be greater, as national targets will certainly limit the ability of individual players to optimize the roll-out for their specific situation. A national roll-out scheme should take this into account and leave either enough degree of freedom, or create the necessary incentives and possibly even subsidies to mitigate the negative impact on parts of the market.

A more gradual roll-out would not only avoid stranded investment and peaking demand for resources, but would also ease the financial burden and could ensure political support for smart metering deployment. Benefits from new technologies and decreasing prices could be more easily accommodated. In such a case the roll-out could be targeted firstly to regions and business sectors where the highest benefits from smart metering are expected. This could, for example, be urban areas with a dense population and in many cases comparably higher per-capita energy consumption.
Rural areas, sparsely populated and characterized by a lower energy demand from consumers would then be fitted with smart metering last. In any case different technological approaches would be required. Whereas in urban areas PLC is likely to be the preferred option, in rural areas smart meters would be typically connected via DSL or GPRS/GSM. This would however depend on the existence of broadband internet connections or a well developed mobile communications network in these areas.

To ensure maximum net benefits it is necessary to take the situation of all stakeholders into account and the impact a smart metering roll-out will have on them. Depending on market structure, market model and targeted objectives, cooperation between stakeholders is crucial for success. This is especially the case if a multi-utility approach is chosen, or if ownership issues affect private property rights. Another key requirement is to raise the necessary awareness of consumers regarding the possibilities provided by this new technology and to take into account concerns at an early stage to ensure public acceptance. Furthermore, the standardization of hardware, software, communication procedures and interfaces may be much easier if a cooperative approach is chosen. A single entity such as a regulator typically lacks full information and may be unable to make the most efficient choices without consulting the other stakeholders.

### 4.3 Role of Regulation

The regulatory framework needs to be properly amended in order to encourage smart metering deployment. However, the role of regulation is highly dependent on the chosen metering market model and deployment strategy. In a liberalized metering environment, regulation’s role in promoting smart metering is by definition limited, e.g. to general market organization tasks. However, metering is not liberalized in most EU Member States and ERRA countries and hence the regulator has direct control. For the sake of argument we therefore assume that, for the assessment of the role of regulation, the metering sector is a regulated monopoly of either the DSO or the MSP and that a high level of market penetration in the short or medium term is a national objective, such as demanded by Directive 2009/72/EC for EU Member States.

In such a case, regulation plays a crucial role for the promotion of smart metering, setting the general framework and by realigning and strengthening the regulatory incentives. Regulation may also provide strong consumer benefits in ERRA countries, such as:

- Educating consumers in advance about smart meter installation, what changes the smart meters will bring and how to adjust to them
- Protecting the privacy of consumers and their energy usage data
• Protecting consumers from unduly rate increases caused by time-of-use pricing or other tariffs that increase energy bills when consumers use energy at times of high demand and are unable to shift their load
• Ensuring the accuracy of smart meter data
• Planning the timing of smart meter rollout in a way that protects consumers

4.3.1 Ensuring Overall Efficiency and Security

The regulator is naturally empowered to set up the national deployment plan. As a first step this means carrying out or commissioning a social cost benefit analysis, probably after initial supporting pilot projects testing technical possibilities and assessing expectable costs and benefits. When devising the deployment plan, it is also necessary to analyze very carefully the potential barriers to a successful smart metering roll-out. The deployment plan should be tailor-made to the existing status quo and policy objectives for smart metering. If the net benefit is assessed as positive, EU Member States need to fulfill the roll-out obligation stemming from Annex I of Directives 2009/72/EC and 2009/73/EC.

It is thus an elementary task of regulation to ensure the overall efficiency of the national deployment strategy. Nevertheless, the extent to which regional and local differences are taken into account is certainly limited in a national roll-out scheme; also the impact for different stakeholders may be varied. It is the task of the regulator to assess such differences, and if deemed necessary to mitigate negative impacts on parts of the market in order to minimize the barriers to smart metering deployment.

After fundamental decisions on smart metering deployment are made, it is the role of regulation to ensure that the targeted objectives are achieved. ERGEG suggests for instance as further exemplary functions of regulation:18
• Ensuring interoperability of metering and communication assets by establishing hard- and software standards
• Setting up the deployment schedule
• Defining minimum service requirements
• Accompanying the roll-out project management

Another issue which is currently evolving as an important task for regulation is the development of a privacy policy and data security standards to ensure customer energy consumption data is not accessed by unauthorized parties or misused. Furthermore, the topic of cyber security is gaining increasing attention, especially in the USA. An interconnected smart metering infrastructure with data

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18 Cf. ERGEG, Public Consultation Paper on Draft Guidelines of Good Practice on Regulatory Aspects of Smart Metering for Electricity and Gas, Ref: E10-RMF-23-03, Brussels, 10 June 2010, p. 32 & 45
transmitted through the public internet might be a target for cyber attacks. The increased potential to be informed about the supply system’s state and to control the system may come at the cost of increased vulnerability against outside attacks. Security standards need to be set up and enforced to mitigate this danger.

4.3.2 Smart Metering Under Revenue Control

The classical role of the regulator is also the need to accommodate the new investments in smart metering during the price control process for metering and/or network usage charges. The application of incentives to promote investment in new metering infrastructure is quite diverse. In many EU Member States, regulators are hesitant to allow for higher user charges to accommodate investments into smart metering. In some of these cases, regulators take up the position that cost coverage should basically come from existing revenues. In Spain for instance, where a national roll-out has already been decided, an increase of the monthly metering fee of around 0.3 € is allowed. In Austria the metering charge for smart metering was set equal to that of conventional metering. In Italy a separate metering tariff is used which should cover costs of smart metering deployment. Italian DSOs who do not meet the scheduled roll-out targets are penalized by reducing the allowed metering revenue. In several other countries investment in smart metering was acknowledged in revenue control without problems, as long as these costs were deemed efficient, as for instance in Germany. In the USA regulators are also relatively hesitant to allow for higher costs passed through to the rate payer. In several states smart metering deployment was only allowed after significant changes were made to the original deployment plans. Major issues have been whether time-of-use tariffs should be made mandatory and how the cost recovery of investment costs should be achieved.

It could be argued that smart metering deployment also results in savings on the supply/network side e.g. due to improved processes, obsolete manual meter readings, less theft and improved asset management (whether these benefits occur (or where) is dependent on the level of vertical integration). The issue of whether the benefits outweigh the costs also has to be considered in the revenue control process. However, experience so far shows that a net benefit for the DSO is highly unlikely if it is the DSO’s responsibility to bear the investment for building up the smart metering infrastructure. A more detailed description of costs and benefits for the different market actors is given in chapter 6.

4.3.3 Tariff Setting

In order to maximize benefits from smart metering market rules, the tariff schemes, technical codes, procedures and processes need to be adjusted to smart metering. If smart metering is about reducing the final energy consumption, one of the major enablers is the application of new tariff schemes. In a more simplistic approach, smart metering is used to offer time-of-use tariff schemes, distinguish-
ing for example between peak, off-peak and super peak periods. This might for example look like the following case, suggested for Ireland.

As the figure shows, the Irish regulator CER recommends a system with basically a day and a night rate with only a slight price difference. However, additionally a third period during evening peak time is distinguished, with a substantially higher price than during the rest of the day (although the prices given are to be considered indicative). In such a tariff system shifting demand from the peak period into the normal day rate period would already generate significant savings. Shifting consumption further into the night time will only have a comparably limited cost decreasing effect for consumers. It also becomes clear that load shifting in such a simple tariff scheme does not necessarily require sophisticated home automation technologies.

![Figure 7: Time-of-use tariff scheme as suggested by CER, Source: CER](image)

However, smart metering might provide many more benefits if load-dependent real-time tariff schemes are applied. Such dynamic tariff schemes take the actual system state into account, the price is for example based on spot-prices and the price signal submitted in real-time to the consumer’s meter and/or in-home display. Especially with a high penetration of intermittent generation the system is less easy to forecast. Simple time-of-use tariffs as in the above example are rather static and are based on traditional load patterns. If intermittent generation becomes the decisive criterion, real-time variable tariffs\(^{19}\) are much more able to positively influence load. Smart metering can enable the application of such tariff schemes and together with home automation technologies consumers can easily adjust their consumption behavior. However, in cases where home automation is not yet well developed simpler tariff schemes would be preferable. In this case, the benefits of smart metering...
ing regarding load management will be less obvious. Such automation enables consumers to shift load automatically; without automation, consumers may be less willing or able to shift their energy usage to inconvenient hours (such as the middle of the night). Thus, it is important not to overstate the effect of smart metering on load shifting without automation. The effect smart metering might have on reductions of consumption is however not influenced by the penetration of home automation technologies. Taking this into account, it is imperative before devising a new tariff scheme to define a clear objective of such tariff adjustment, i.e. whether the aim is to reduce peak load or rather to incentivize consumers to reduce their electricity consumption.

Such tariff schemes, raising prices in peak periods and decreasing those in off-peak periods, may only lead to serious cost savings for consumers if price elasticity\(^{20}\) is sufficiently high. The impact of adjusted tariff schemes is based on the assumption that the feedback provided by smart metering will have an increasing effect on price elasticity of demand. Price elasticity can be influenced by increasing consumer’s awareness, involvement and affinity towards energy savings, for instance by accompanying informational campaigns and also through constant comprehensive feedback on consumption and costs. Home automation will also increase the consumer’s ability to react to changing tariffs. If price elasticity is too low and consumers do not react to changed tariff schemes, these might easily lead to higher costs. To free consumers of this risk, tariff schemes could only be changed in such a way that rebates are offered in off-peak periods. However, such tariffs may easily create misguided incentives to increase overall energy consumption without a decreasing effect in peak periods.

In countries where final consumption tariffs are subject to regulation, the requirement for adjusted tariff schemes needs to be taken into account. New, innovative tariff schemes have to be facilitated by regulation. Even if tariff schemes are not regulated and suppliers are free to adapt to smart metering, this might be limited due to existing regulations on the network side. Network tariffs for instance are generally flat. If consumers have an incentive to consume in a ‘system-friendly’ manner, dynamic (i.e. time and load dependent) network tariffs might give additional leverage for shifting or reducing demand.

Another potential barrier for consumers to fully benefit from adjusting their consumption to the system needs stems from the application of standard load profiles.\(^{21}\) If suppliers still need to procure energy according to the aggregated standard load profiles of their customers, potential benefits from an optimized procurement cannot be realized.

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\(^{20}\) The price elasticity of demand describes the dependency between a price change and the quantity demanded. High price elasticity means that demand is influenced stronger by price changes, i.e. if the price increases demand will decrease noticeably.

\(^{21}\) In these cases small consumer’s consumption is forecast based on standardized load profiles and suppliers have to inject exactly these forecasted volumes into the grid. Smart metering changes consumption behavior in a way that the application of standard load profiles needs to be adjusted. It seems for instance reasonable to treat customers with smart meters similar to larger, real-time metered commercial customers.
4.3.4 Enhanced Regulatory Performance

Regulation should not only play an active role in order to promote smart metering; it can also use this new technology to generate a better understanding of the network and to improve the existing arrangements. Smart metering can be especially valuable if a quality of supply regulation scheme is applied or needs to be set-up. Such a regulatory scheme is typically based on an incentive regulation regime but includes the quality of supply as one of the output factors measured, either as integrated part of a general efficiency assessment or as separate element of the revenue control formula.

If widely deployed, smart metering provides accurate information on and enables monitoring of voltage and power quality, interruption duration and frequency. In particular very short interruptions are often not recorded by existing systems. Smart metering would thus provide the basis to significantly improve the regulator’s data basis and increase feasibility of quality regulation schemes.

Moreover, smart metering also enables network operators to improve quality of supply, for instance by faster outage detection. It can thus be a very powerful regulatory tool to generally improve quality of supply. In Italy, for example, the regulator created an incentive for DSOs to actively use smart metering to improve quality of supply. Subject to the provision that DSOs also deploy smart metering faster than originally scheduled, they receive an extra payment of 15 € per customer.

5. Potential Barriers to Smart Metering Deployment

5.1 Consumer Resistance

Smart metering may not be perceived as positive by the majority of consumers. In most cases consumer resistance can be observed as driven primarily by two reasons:

- Consumers might fear that security and privacy of data gathered by smart metering cannot be guaranteed and hence unauthorized parties might have access to private data.
- Consumers might also fear that the costs for deploying a smart metering infrastructure end up with them, leading to higher energy costs, whereas their benefits might prove to be overestimated.

The first case is highly relevant as the amount of data collected possibly allows very detailed conclusions on the lifestyle and daily routines of households. The real-time transmission of this data from the consumer’s site to the data center creates some vulnerability which did not earlier exist when this data was simply not generated. At the same time data security and consumer privacy issues are
vital for the success of smart metering deployment and public acceptance. In the Netherlands for instance privacy concerns led to a serious delay in the roll-out scheme, when in April 2009 the Dutch Senate rejected a proposal for mandatory smart metering deployment. It is hence very important that that data is not accessed by unauthorized parties and that there are clear regulatory provisions on how data is gathered, processed, stored and evaluated, and who has access to which data. In order to protect the data against unauthorized access adequate measures (encryption, digital signatures) need to be taken. This is particularly important when PLC technology is used to transmit data from the consumer’s site to a data concentrator, as potentially every user connected to the same power line is able to intercept the communication between meter and data concentrator.

Data should be generally protected by privacy law but, as the amount of personal data collected with smart metering (and the potential harm which could be done with it) is much greater than ever before, new legislation may be required.

The second case seems to be less relevant, as experience shows that the opposite is more likely. Consumers might benefit the most from smart metering when they are given the means to reduce energy costs by identifying savings potentials or by adjusting their consumption according to new tariff schemes, whereas they are often protected from direct cost pass-through by regulatory authorities. In these cases consumers will benefit significantly from smart metering whereas costs are most likely borne by network or metering operators, cf. section 4.3.2.22 Nevertheless, political and social sensitivities in many of the ERRA countries would require addressing these issues with special care. There have been multiple examples where consumers and politicians in these countries have been opposing price increases regardless of whether these increases had been driven by objective economic reasons.

In both cases, the main problems and thus the main instruments to mitigate consumer resistance are a lack of consumer awareness, trust and knowledge. It becomes clear that to ensure successful smart metering deployment an accompanying information campaign is needed to, firstly, create the necessary acceptance from the consumer and, secondly, to enable the consumer to benefit from the possibilities smart metering provides. This is particular relevant for the ERRA countries where in many cases customers are not well informed due to simple disinterest and/or lack of organized information channels using customer associations or industry information centers.

Furthermore, the establishment of the smart metering deployment strategy should involve all stakeholders and take any concerns into consideration at an early stage.

22 However, this also may lead to opposition towards smart metering deployment, although not from consumers, as discussed in section 5.3.
5.2 Legal/Regulatory Barriers

As shown in chapter 4, regulation, i.e. regulatory authorities and governmental bodies, has to play a significant part in assessing a potential smart metering deployment and afterwards if smart metering is to be promoted (because sound assessment of costs and benefits proved the economic efficiency of such an investment). Regulatory and legal barriers may stem essentially from two reasons:

- The necessary legal and regulatory framework is not in place at all
- The existing framework contains provisions which hinder smart metering deployment, increase costs or decrease benefits

In some cases, for instance in the USA, regulators also opposed smart metering. However, this cannot be seen as a regulatory barrier as such, as typically in these cases the regulator was not convinced that smart metering would lead to an overall welfare increase and feared that rate payers would only be harmed by extra costs of the smart metering deployment. This may sometimes be the case, if the cost-benefit assessment is conducted for instance by the utility itself and subsequently may tend to be biased in favor of the utility.

We discuss several aspects below to provide an explicit focus on the situation in the ERRA countries.

5.2.1 Revenue / Tariff Setting and Incorporation of Costs of Smart Metering

A typical barrier could consist in the lack of a clear policy framework (underpinned by national legislation) on deploying a smart metering infrastructure or at least a clear commitment that (efficient) costs for building up and operating a smart metering infrastructure are accommodated in tariff regulation. Also a lack of well-defined responsibilities might prove to be a barrier to the promotion of smart metering. The regulatory regimes in the ERRA countries usually apply rate-of-return regulation or linked revenue caps. Under these regimes the regulator sets the allowed network revenue of the regulated entity for each year of the regulatory period by assessing the investments and operating costs. In this assessment the regulator may also incorporate efficiency increase requirements in the revenue projections. The use of such regulatory models and the fact that metering business remains regulated (and in many cases is part of the network infrastructure) provide an appropriate platform for integration of costs of smart meters in the network price control. However one major issue remains, this is the extent to which the allowed revenue and tariffs reflect the underlying costs for the provision of regulated services. This issue has been observed in many of the ERRA countries.

Normative pricing principles require primarily economic efficiency and cost recovery. However, introducing cost reflective tariffs often results in high price increases for small consumers. While the
computation of cost reflective tariffs is a quantitative effort and depends mainly on the quality of available data and professional knowledge, their implementation for all customer categories has been usually a gradual process to achieve political acceptability and address social affordability.

While the social and political constraints are understandable issues, it is a fact that non-cost reflective prices cause distortions in price signals and consumer behavior. In the context of smart metering non-cost reflective prices may encourage energy consumption and undermine energy savings and the potential benefits (see next section). Therefore it remains essential that regulators should strive to adopt end-user prices as well as network tariffs that reflect the costs of provision of regulated services to specific groups of customers.

5.2.2 Implementation of Time-of-Use Pricing

If, for instance, tariff regulation does not address the implementation of time-of-use or dynamic tariffs, benefits from smart metering deployment cannot fully unfold. Hence if such an option is not even assessed in the social cost-benefit analysis, the case for smart metering might be hindered from the beginning. This is of particular relevance for the ERRA countries where retail price control continues to exist. In a liberalized electricity industry with functional competitive wholesale and retail markets, regulation should focus on the monopoly network business only. The end-user prices would be subject to monitoring and ex-post control by the national competition authorities.

However, in the majority of the ERRA countries the liberalization has been designed as a gradual process with step-by-step market opening. Regulatory arrangements still require regulated energy prices for those customers that are not (yet) entitled to choose their suppliers (captive consumers) and/or no effective competition is feasible due to highly concentrated retail markets. In contrast to deregulated electricity markets where suppliers are free to agree with customers on the level and structure of their prices, regulated retail markets apply tariffs approved by regulators. Regulators are in charge of setting the allowed revenue and the rules for cost allocation and tariff setting. Therefore it is essential that regulators encourage and design tariff schemes using time-of-use models. Such schemes have been already applied in many countries in the past, e.g. Serbia, Romania, Bulgaria, Macedonia, etc., using measurements from a simple period or interval meters. With the penetration of smart metering one can develop further and increase the degree of sophistication of these schemes.

5.2.3 Use of Standard Load Profiles

Currently suppliers operating on the competitive retail markets use standard load profiles to schedule their energy purchases. With the implementation of smart metering real-time data with high granularity will become available. If regulatory and legal frameworks continue imposing obligations on suppliers to procure and deliver energy into the network based on standard load profiles, the advan-
tages offered by smart metering will not be realized. This is particularly relevant for the application of advanced pricing schemes which can be supported by real-time metering and flexible demand response. If the metered data is based further on estimated load profiles, suppliers will not be encouraged to pass on benefits from energy procurement to customers, e.g. in cases where peak loads can be reduced or demand predictability is improved. Therefore implementation of smart metering should be accompanied by an amendment of the retail market rules.

5.2.4 Other Technical Regulation

In other cases, technical regulations which have evolved historically may not correspond to the new technology or may no longer be in accordance with one other. If, for example, gas and electricity meters have different calibration periods and hence replacement cycles, additional costs may occur in a multi-utility approach.

5.3 Economic Barriers

Several economic barriers need to be dealt with in order to successfully deploy smart metering. One of the primary economic barriers is that whereas costs for installing and operating a smart metering infrastructure can be assessed comparably easily, there is often high uncertainty regarding the benefits. Many benefits either rely on assumptions and forecasts, such as the amount of energy which might be saved by smart metering. Other benefits are difficult to reliably quantify, such as a gain in leisure time for a consumer due to fewer errors in invoices and hence less time spent on the customer service hotline.

Moreover, if costs and benefits are assessed with the appropriate due diligence, costs may be overestimated whereas benefits might be underestimated. Altogether this would result in a cost-benefit analysis which may be biased against smart metering roll-out.

Another serious economic barrier is a possible split between the cost bearing party and the beneficiaries. This would for instance be the case if costs were fully borne by DSOs within the existing network or metering charges, whereas energy savings as a major benefit occur on the consumer’s side. Full-scale smart metering deployment is highly capital intensive, thus exposing the responsible party to significant risk. In many countries, direct subsidies from governments for smart metering are not to be expected, and thus the network operators are reliant on cost coverage by usage tariffs. Therefore transparent arrangements for incorporating costs in the allowed revenue are required, as is a clear commitment by regulatory authorities or government bodies. If regulators opt for efficient costs of smart metering deployment to be covered by regulated network or metering charges, but the allowed revenue is deemed insufficient by the party responsible for bearing the investment, this
will most certainly become a serious barrier to smart metering deployment. We have explained the role of setting cost-reflective tariffs in the previous section.

5.4 Technical Barriers

One of the main technical barriers to smart metering is that commercially available smart metering components often lack interoperability due to highly proprietary solutions. Open hardware and communication standards are still under discussion/development, e.g. the Mandate M/441 which was given to CEN, CENELEC and ETSI by the European Commission, or the Open Meter project, funded by the European Commission within the Seventh Framework Programme.23

Smart metering hardware is offered by some producers. So far the market is still small, but it has been developing rapidly in recent years. Hard- and software as well as communication infrastructure providers are organized in the European Smart Metering Industry Group (ESMIG). Many of the member companies are small, but also big players such as Siemens, IBM and ABB are present. Due to an absence of standards, manufacturers have developed a variety of proprietary solutions while interoperability of devices produced by different manufacturers is lacking.

The existing industry structure and the lack of standards lead to the following problems:

- Due to the number of players and the limited size of the market, economies of scale are not achieved, resulting in fairly high costs for smart metering components. This is however expected to change in the future if a real mass market is established.
- Devices of different manufacturers are most often incompatible. This carries the inherent danger of stranded investment, e.g. if at a later stage a gas meter shall be integrated, or if in the case of a supplier change, the meter is not compatible with the supplier’s infrastructure.
- Devices are often designed as stand-alone, thus complicating a modular approach where all components could be replaced separately. The modular approach is further impeded by the lack of interoperability.
- The lack of modularity is hindering the easy adoption of a smart metering infrastructure to specific needs of an individual roll-out scheme. Specially designed solutions are often needed to match individual requirements, resulting in higher specific costs.
- Cooperation between DSOs or Metering Service Providers and the smart metering supply industry is weak; development of smart metering could clearly be improved by better cooperation and a more goal-oriented component design.

23 http://www.openmeter.com
• Further development of smart metering technology is expected in the future. Metering devices installed in recent years may need to be replaced before the end of their economic lifetime to enable new, innovative services.

• Installation of a smart metering infrastructure is a highly demanding technical task requiring a qualified labor force. A short-term large-scale roll-out might be hindered by a lack of resources. Furthermore, production capacities of smart metering suppliers are limited, which might lead to supply problems if a short-term roll-out is mandated in several European countries at the same time.

6. Costs and Benefits

6.1 Definition of Costs and Benefits

Major benefits from smart metering generally result from lower metering costs, final energy savings at households and small commercial consumers, easy detection of theft, improved invoicing procedures and less bad debt. Another important issue is the possibility to improve quality of supply and service with smart metering by faster outage detection and the use of voltage and power quality monitoring. In combination with the ‘right’ incentives, smart metering can generate benefits from changed consumption behavior, i.e. demand response, and hence reduced peak-load and more load shifted into off-peak periods.

However, drivers for implementing a smart metering infrastructure can be quite diverse. In Italy for instance the reduction of fraud was one of the main motivations, whereas in Sweden DSOs were triggered to roll-out smart meters by the legal requirement to invoice monthly based on actual meter readings. In most European countries, the increase of energy efficiency (reduction of final energy consumption) driven by climate policy is at the top of the agenda, whereas in the US, due to a capacity shortage, demand side management is the key driver for smart metering deployment. Subsequently the actual design of the smart metering infrastructure and the accompanying framework is very much dependent on the objectives pursued. Thus, the potential benefits of smart metering can also be quite varied, i.e. they are strongly dependent on the policy objectives and the associated regulatory framework.

Most of the costs and some of the benefits related to smart metering can be estimated before making a roll-out decision. Due to the fact that in future new services and functionalities will most certainly arise, additional benefits will appear that cannot be properly estimated at this stage. Manufacturers of products such as household appliances and the service industry will adapt to smart metering technology and will develop and offer a wide range of specially designed products and ser-
vices, e.g. further increasing energy efficiency by intelligent household control or enhancing consumer welfare with increased comfort.

Benefits are also highly dependent on the local circumstances and status quo. The load shifting and energy savings potential of smart metering is strongly related to the types of energy consumption and the consumption patterns. For example, usage of electricity for heating and cooling can be shifted easily. However, this will require automation, which is less likely to be available for household consumers compared to industrial and larger commercial consumers. With cooling and heating as loads which are relatively easy to shift, the percentage of load which could be shifted is much higher in a country where for instance air-conditioning is widely applied.

The same mechanism is valid for energy savings. In countries with very high (careless) energy consumption, the potential to significantly reduce energy consumption might be comparably high. Likewise, in countries where household budgets are typically very limited and energy costs are consuming larger shares of the budget, the incentive to realize cost cuttings, e.g. by energy savings or demand response measures is much stronger. The latter is relevant for several of the ERRA countries.

In order to assess the costs and benefits of a smart metering roll-out, a social cost-benefit analysis is required. Such cost-benefit analysis is concerned with the theory and application of criteria for investment decision making. If the social cost-benefit analysis result is positive, i.e. the investment overall generates a positive net benefit (benefits higher than costs), the investment leads to an economic welfare gain and should thus be made. For the assessment of costs and benefits, the impact on stakeholders should be evaluated separately. This provides an insight into the redistribution effects, i.e. who will bear the costs and who will bear the benefits. For a social cost-benefit analysis on the national deployment of smart metering, the usual stakeholders distinguished are DSOs (and metering service providers, if applicable), final consumers and suppliers. Additionally the supplementary positive effects on society can be considered.

![Figure 8: Possible benefits for separate stakeholder](image-url)
Note: The picture provides a generalized overview and assumes that metering is a responsibility of DSOs.

Detailed information on costs and benefits is needed as input data for the social cost-benefit analysis. As discussed in section 5.3, the input for the cost-benefit analysis can easily lead to a bias against smart metering roll-out, thus the input has to be assessed and evaluated carefully. The effects can be divided into direct and indirect effects. Direct effects can be quantified relatively easily, e.g. such as the cost of installing a smart metering infrastructure. Indirect effects depend in most cases on the expected response and behavioral changes of the affected parties, hence they have to be estimated. Typical examples for indirect effects for instance are benefits resulting from energy savings, reduction of greenhouse gas emissions or possible positive effects on the labor market.

The cost categories which generally occur are investment costs, operation costs and costs due to stranded investment.24 Generally applicable on the benefit side are energy savings, improvements in metering and billing, saved investments and possibly a higher quality of supply.

### 6.2 Potential Costs for a Smart Metering Infrastructure

Building up a smart metering infrastructure is associated with substantial costs of electronic components and communication infrastructure. The various data used for this chapter are obtained from pilot projects, manufacturers and energy suppliers as well as from other references, and do not easily present a consistent picture of the expected costs of introducing smart metering. One reason for the high bandwidth of cost expectations is the enormous development in the markets for electronic components and communications infrastructure. In this paper we assume that strong growth and significantly falling prices will continue. The costs of owning and operating the communications infrastructure will also decrease. It seems reasonable to expect an annual costs saving potential of 5-10%.

There is a great variety in prices for electronic meters. These price differences result primarily from different functions (interfaces, data storage, etc.), particularly if the communication unit is already integrated into the meter. Moreover, the number of procured meters has significant impact. The empirical analysis within the KEMA study for the German Federal Ministry for Economics and Technology showed average costs of 108-126 € for smart metering devices.25 The costs for a simpler meter with remote meter reading functionality were estimated at 40-60 €, for a standard electronic

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24 Strictly speaking cost-benefit analysis should only consider the future incremental costs and benefits. However the options for deployment strategies for smart metering can include different timetables in this way avoiding to a significant extent the need to scrap existing functional metering stock.

25 KEMA, Endenergieeinsparungen durch den Einsatz intelligenter Messverfahren (Smart Metering), Final Report, Bonn, June 2009

meter 36 € was assumed. But these simpler meters have no integrated communication module; hence they have to be connected with a communication unit, for example with a MUC-C. The costs of a MUC-C are estimated at about 60-120 €.

In pilot projects, the costs of data concentrators were identified as 350-700 €, the installation costs as 50-144 €. Using one concentrator for typically 50-100 meters costs thus 4.5-9 € per meter.

A separate communication module results in higher acquisition costs than a communication module which is already integrated into the meter (i.e. in most cases this is the electricity meter, theoretically all other meters can also be used), if not several meters are connected to this communication module. The reasons for different concepts being applied in several cases are different assumptions regarding the lifetime of the devices, multi-utility strategies, as well as different market expectations.

GPRS/GSM-enabled devices are more expensive than meters with a PLC communication, because the modulation of a PLC-signal is technically much easier than a GPRS connection. The price difference is about 35-50 € per meter. For DSL compatible meters, the additional costs are higher, as there is no broad market for this solution. It is expected that a significant potential for economies of scale exists, for DSL as well as for GPRS devices. The majority of the currently installed units are PLC devices. Regarding the operational costs of DSL, costs of disturbances have to be considered. By using parts of the customer’s infrastructure for the DSL based communication, it is likely that more intensive customer support will be required when the customer’s internet connection is disturbed, irrespective of the reason for the disturbance.

KEMA’s observation of the German market is that almost all utilities consider comprehensive PLC as the most cost effective option, requiring a significant market penetration (30-70% are considered significant). Only for isolated buildings (e.g. in rural areas) GPRS seems to be the most cost effective option. It should be noted however that in Germany most pilot projects or smart metering roll-out plans are from DSOs, who take care of the bulk of supply and are responsible for metering in their supply area.

The following table shows the costs for the technical infrastructure of smart metering:

<table>
<thead>
<tr>
<th>Costs</th>
<th>KEMA Assumption</th>
<th>Min-Variation</th>
<th>Max-Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procurement costs smart meter (€)</td>
<td>45</td>
<td>35</td>
<td>110</td>
</tr>
<tr>
<td>Installation costs smart meter</td>
<td>18</td>
<td>13</td>
<td>28</td>
</tr>
<tr>
<td>electricity (€)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Additional installation costs (selective Roll-Out) (€)</td>
<td>30</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>Annual operating costs smart meter</td>
<td>0.6</td>
<td>0.4</td>
<td>2.9</td>
</tr>
<tr>
<td>(electricity) (€)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Procurement costs MUC-C (€)</td>
<td>80</td>
<td>60</td>
<td>120</td>
</tr>
<tr>
<td>Installation costs MUC-C (€)</td>
<td>13</td>
<td>8</td>
<td>20</td>
</tr>
</tbody>
</table>
### Table 2: Indication of potential costs for a smart metering infrastructure

<table>
<thead>
<tr>
<th></th>
<th>KEMA Assumption</th>
<th>Min-Variation</th>
<th>Max-Variation</th>
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<td>Annual operating/maintenance costs MUC-C (€)</td>
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<td>5.8</td>
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<td>Procurement costs smart meter (gas) (€)</td>
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<td>Installation costs smart meter (gas) (€)</td>
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</tr>
<tr>
<td>Installation costs PLC per smart meter (€)</td>
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<tr>
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<td>2</td>
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<td>Additional costs GPRS/GSM per smart meter (€)</td>
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<td>Annual operating costs incl. queries DSL-Modem (€)</td>
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6.3 **Benefits to Network Operator**

Smart metering has several potential benefits for network operators. When widely deployed, it allocates better information on the low voltage distribution network, offering a range of potential savings to distribution operators. Benefits, which appear system-wide, derive from optimizing distribution operations, from improving network reliability and from the ways in which smart metering improves quality of service, e.g. by supporting outage detection and reduction of restoration time.

The most important potential benefits for network operators are listed below:

- **Improved detection of network losses and fraud/theft**
  
  Smart metering allows for an easier detection of previously unmeasured consumption that resulted from bypassing the meter. In addition, smart meters provide more accurate information about the location of losses and theft. In Italy for instance non-technical losses were one of the main reasons for deploying smart metering. Smart meters can be fitted with anti-tampering devices alerting the DSO when manipulation of the meter is attempted.\(^{26}\) All this appears extremely relevant for the majority of the ERRA countries where industry and regu-

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\(^{26}\) Reduction of fraud is not an immediate economic benefit from a societal perspective, as consumption is not directly influenced and no additional welfare is generated. Nevertheless, if payment discipline can be improved, energy savings are also likely to be triggered.
lators have been struggling with the design and implementation of plans for reduction of commercial losses.

- **Reduction of peak load**
  By providing customers with information on consumption and prices and by offering incentive tariffs, customers are able to shift their energy consumption into times when energy prices are on a lower level, thus network operators could reduce peak load situations.

- **(Faster) Identification of fault locations**
  With smart metering the utility automatically knows where the power is out and can dispatch crews to restore it immediately. Smart metering can help grid operators to locate faults more quickly, thereby reducing the time period between the time the fault occurs and the time the grid operator’s control center receives this information. By identifying fault locations faster, the outage time can be reduced. This provides an obvious benefit to consumers and savings to the distributor from reduced costs by more accurately dispatching crews. If a quality regulation scheme is applied, reduced outage duration also improves the DSO’s performance from the regulatory perspective. Several regulators in the ERRA countries (Hungary, Romania, Poland) have implemented quality of supply incentive schemes linking the reliability network performance (number and duration of outages) with the allowed revenue. Other regulators are in the process of designing such regulation (Macedonia, Serbia).

- **Process optimization/savings of operational costs**
  Due to the fact that smart metering is integrated into the IT infrastructure of the network operator, there is a high potential for process optimization and savings in operational costs. Some benefits can also be gained from a multi-utility approach integrating gas, district heating or drinking water metering. The impact is however dependent on the market model applied.

- **Network asset management and efficient infrastructure**
  Smart metering generates real-time, accurate and comprehensive information on the distribution network (e.g. voltage quality, losses), which might improve distribution network operation. Accurate information on what is happening in the network also provides a basis for sound investment planning.

- **System security**
  Smart metering provides the ability to remotely disconnect/reconnect consumers and for remote reduction/restoration of the available power. Combined with an efficient communication system, this can help to maintain network security.

With DSOs providing the metering services by default in most ERRA countries, benefits stemming from improved service provision or cost savings in the metering business are allocated to the

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27 Remote dis-/reconnection of gas supply is theoretically also possible, however if applied, it is subject to much tighter security provisions. For gas, before reconnection of supply all appliances and valves must be checked in order to guarantee safety. This can be done by the consumer with the necessary instructions provided via smart metering.
DSOs. The typical benefit which applies in particular on the side of the metering responsible party is:

- **Remote meter reading makes manual meter reading obsolete**
  With smart metering, digital meter data are automatically submitted to the DSO’s data center. Manual meter readings and manual entering of meter data into data management systems are no longer required. Data can be easily processed and evaluated and meter-to-bill operations can be significantly improved.29

### 6.4 Benefits to Supplier

Depending on the market model, the supplier may not be identical to the network operator. In such cases, the impact of smart metering on suppliers has to be distinguished from the impact on network operators. The latter will require a closer analysis of each party’s tasks.

Smart metering offers suppliers several typical advantages, such as:

- **Facilitation of changing suppliers**
  Due to real-time metering suppliers can be changed more easily and quickly. Theoretically changes are possible in real-time or at very short notice and on any chosen date.

- **Pricing options**
  With smart metering, suppliers could use actual load profiles of their customer profile instead of standard load profiles, if the system allows for this, and could thus make savings on the procurement side if energy consumption of their customer portfolio shows an advantageous pattern. Thereby suppliers could have the opportunity to also offer customized contracts reflecting individual consumption patterns. These contracts may include time-of-use or more sophisticated tariff elements and might also provide for automatic demand side management.

- **Higher level of data accuracy**
  Due to fewer faulty meter readings, mistakes in the data processing and invoicing process are reduced hence resulting in less customer complaints. Costs of meter-to-bill operations and customer complaint handling can be reduced.30

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28 However, it should be kept in mind that the metering function could also be with the supplier or with a completely separated entity.

29 It should be noted however that especially where a large labor force is employed for manual monthly meter readings this might have a serious negative effect on employment.

30 Even if metering is provided by a separate entity, invoicing is carried out by the supplier, hence complaints due to faulty readings are generally directed to the supplier.
• **Energy management services**
  The information on final consumer’s consumption behavior provided by smart metering enables the development of new services aiming at helping the customer to become more energy efficient or to generate added value for the consumer.

### 6.5 Benefits to Consumers

Using smart metering systems may benefit consumers in a variety of ways. The replacement of analog meters by smart meters gives consumers detailed information, allowing them to make better decisions, e.g. choosing the most convenient supplier or choosing when to connect/disconnect some devices. Achieving energy savings with smart metering is highly dependent on the effectiveness of the feedback on energy use given to consumers and the willingness and ability of consumers to respond to this feedback. Several previous studies show a broad range of potential savings. Recent comprehensive studies and also KEMA’s own observations show that electricity consumption savings between 5% and 10% appear realistic. However, some consumers may not have the ability or show willingness to shift or reduce their demand, and the possibility of higher energy bills for those consumers cannot be ignored.

The following list describes some potential benefits to consumers:

- **Consumer’s awareness regarding energy consumption and energy savings**
  With smart metering consumer’s energy consumption during different periods of the day can be recorded and evaluated; actual and historic consumption data can be shown on an in-home display or on a computer screen, either provided by a direct data link or on a web page fed with the meter data. Thereby customers are able to understand the impact of individual appliances or a certain consumption behavior on their energy bill. The information provided might be extended to monetary values, i.e. costs of consumption, or environmental effects, such as resulting greenhouse gas emissions. Constant feedback on consumption and associated costs will increase the consumer’s awareness and his willingness to make energy savings. However, it should be clear that consumer education is a necessary element in order to achieve changes in consumption behavior. The existence of the smart meter or some consumption feedback itself will not necessarily result in success. The consumer needs to be taught how to use this new information in order to really achieve sustainable energy savings.

- **Changing the supplier becomes easier**

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Smart meters can be read at any time on request. Automation and simplification of data exchange through smart metering should speed up the process for changing suppliers and simplify the action required from the customer to make the change.

- **Accurate consumption payments**
  With smart metering, invoicing is based on real meter data rather than estimated consumption (applies only where manual meter reading does not take place monthly). Customers no longer face imposed under/over payments which might require settling at a later date. This generates added benefits such as improved customer satisfaction resulting in fewer customer complaints, especially when the settlement occurs after several months. It is also possible for a customer to agree with the respective supplier on how frequently invoicing takes place and to receive an invoice on demand (e.g. when moving from one home to another).

- **New services, tariff variety and flexibility**
  The possibility to offer real-time pricing and innovative tariffs, as well as interfaces between smart metering and household appliances could result in new types of energy services being available to customers – to help manage consumption (and costs) and to promote more energy efficient and ‘green’ energy networks. Smart metering, for example when combined with time-of-use tariffs or load-variable tariffs, allows customers to manage their energy consumption and thus offers them savings on their energy bills. Shifting certain usage (e.g. dishwasher, heating, cooling) to cheaper periods not only offers cost savings to customers. Smart meters can also facilitate pre-payment options which allow customers to pay in advance and hence to better manage their budgets.

### 6.6 Benefits to Society

Benefits to society from smart metering deployment result mainly from the avoided production and network costs and the associated greenhouse gas emissions. Smart metering can be a valuable instrument in promoting energy efficiency and reducing final energy consumption in total terms. Smart metering can provide consumers with clear information on their consumption and associated costs, thus providing strong incentives to reduce energy consumption.

Additionally, if demand response mechanisms are established (through smart metering), the power system is able to accommodate a high penetration of (mostly intermittent) generation from renewable energies. In a situation with low demand and high production from wind and solar, situations might occur where the available electricity exceeds demand. When this occurs, conventional generation may be further reduced, running at inefficient operating points or even shut-down with resulting start-up costs, or generation from renewables could be shut down wasting electricity that would be produced at no additional cost and free of emissions. Demand response shifting load into off-peak or strong wind periods can help to avoid such inefficiencies. Additionally, smart metering/demand re-
sponse might also lead to a lower system peak reducing the need to construct new peak-load generation capacity (and probably also network expansion investment).

The major part of a reduction in greenhouse gas emissions will probably result from the final energy savings. Given the comparably large share of energy demand for space heating, a smart metering approach extending to other utilities besides electricity seems to be very promising. Even if percentile savings may be small, in absolute terms reductions in heat demand might easily exceed electricity savings. Moreover, society would benefit from increased welfare due to an investment program like the full-scale roll-out of smart metering, with a positive effect for example on the labor market.

6.7 Benefits to Regulatory Authorities

Regulatory authorities may also benefit from smart metering deployment, especially when applying a quality regulation scheme, where smart metering provides the regulator with far better statistics on reliability performance (number and duration of outages). With smart metering all outages can be recorded, regardless of the outage duration and the voltage level(s) affected. The data gathered with smart metering can be used to design adequate incentive schemes for quality regulation resulting in higher levels of quality of supply.

Additionally smart metering enables improved monitoring of voltage quality (voltage levels, dips). To perform this task meters should be equipped with power quality monitoring functions. It might be sufficient to equip only a certain share of electricity meters with these monitoring functions.

Regulatory authorities play a key role in promoting smart metering and at the same time ensuring overall efficiency and cost-effectiveness. Thus smart metering is not only a valuable tool for regulation itself; it also provides the regulatory authority with a completely new challenge, especially if it is seen in connection with the development of a smart grid, increasing the importance of the regulatory authority and the need for its knowledge and market insight.

6.8 New Services

Smart metering will most certainly open up markets for new services, some of which have not yet been anticipated. Obvious new services which could emerge from smart metering deployment are new tariff designs, demand response and those in the field of home automation.

32 Traditionally, automatic fault monitoring extends only to the medium voltage level, whereas faults on the low voltage level often go unnoticed until consumers alert the DSO.
6.8.1 Innovative Tariff Schemes

Firstly, the smart metering functionality to register load enables innovative tariff schemes. In the most basic case, time-of-use tariffs with only two time periods are applied. Such tariffs are already widely used simply distinguishing between peak and off-peak periods. They are for example very common where electricity is used for heating with storage heaters. However, with electronic meters such tariffs are more easily applied and moreover easily enhanced. Smart metering based time-of-use tariffs often apply more complicated tariff schemes, e.g. distinguishing between peak, off-peak and super-peak periods and also between normal working days and weekends or public holidays, cf. section 4.3. In a further step, dynamic tariff schemes could be linked to real-time spot prices, enabling consumers to benefit even further from an adaption of consumption patterns to the system state.

With smart metering, a real-time price signal could be submitted to the consumer, providing him with full information on costs actually incurred and the savings potential if consumption is adjusted. First of all such adaption will not lead to decreased consumption but primarily to a load shift into more favorable periods. However, depending on the kind of load shed in high price periods, it will not be compensated necessarily to its full extent in low price periods, resulting in energy savings.

New tariff schemes are certainly of high practical relevance, as major benefits possibly stemming from a smart metering roll-out cannot be achieved without innovative tariff schemes. Together with new tariff schemes, new payment schemes will also emerge. Smart metering can enable or simplify a wide variety of possible payment schemes, such as for instance prepayment schemes. In the Netherlands and in the UK, prepayment schemes are already fairly common, especially for bad creditors. As in these payment schemes, feedback on the level of consumption and associated costs is given in a very direct way, and energy saving incentives are comparably strong.

6.8.2 Home Automation Services

Consumers can further benefit from new tariff schemes if they do not need to adapt to price signals manually. Home-automation technology will provide consumers with the necessary means to automatically adapt to real-time price signals and optimize energy consumption. Possibly such services will be offered by several parties, e.g. manufacturers of household appliances, electricity suppliers or independent service providers. A supplier could for example offer electricity supply at comparably low prices together with the right to curtail customer’s consumption by remotely controlling certain

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33 New tariff schemes make the most sense for electricity, as the system is more fragile with respect to the exact balance between supply and demand and there is a clear intra-day peaking characteristic in consumption patterns. For gas and heat demand, tariff schemes to optimize the point in time of consumption would not lead to equally useful results, as for instance final consumers demand cannot be shifted to flatten the peak in the annual profile. On the other hand, for gas significant storage capacities are available at economically efficient costs, which is not the case for electricity.
appliances. It seems likely that such schemes are more successful if an individual consumer needs to do less to manage his consumption, while at the same time it should not affect comfort beyond a certain level.

6.8.3 Consumers as Active Market Participants

Smart metering can also enable the active participation of consumers on the ancillary and system services market, if the ability to shift load created by smart metering is bundled by a service provider for a large group of consumers and then offered on the market.\(^{34}\) In these cases not only consumer load but also available generation capacities, e.g. from solar panels or microgeneration can be combined to a so-called virtual power plant, providing for instance reserve energy.

All these services concerning tariffs and home automation target some kind of demand side management in order to reduce peak loads, thus avoiding investments in expensive peak load generation capacity (often gas turbines with low levels of full-load hours) and possibly also network capacity. In the USA, demand response has already been on the agenda for some years,\(^{35}\) whereas in Europe it is only slowly gaining momentum. The key driver for demand response in the USA is the – compared to Europe – very tight generation situation, which, among other things, led to the spectacular outages in California and on the East Coast a few years ago. For the USA, the potential for demand response is estimated as 5% of the annual system peak load. For Europe, the estimations are somewhat lower at around 3%.\(^{36}\) However, in most European countries, demand response was not considered to be so important in recent years, although this is slowly changing with the discussions about the integration of large shares of renewable energies and the need for a ‘smarter grid’.

6.8.4 Other New Services

Other new services which could emerge in a smart metering environment will not necessarily be associated with energy consumption. Instead they will just be piggybacked on the existing communication infrastructure. However, such services will not necessarily require smart metering; probably every other reliable communication infrastructure could be used. Such services will typically be safety and security alarms, such as fire or burglar alarms. Alarms could also be sent in case of unusual consumption patterns, e.g. identifying possible need for help. Also the smart metering infrastructure could be used to submit home alerts of elderly or disabled people.

\(^{34}\) To take availability factors into account, the capacity firmly offered on the market would be in the magnitude of 10% to 25% of the total movable load.

\(^{35}\) Cf. e.g. Borenstein, S., Jaske, M., Rosenfeld, A., Dynamic Pricing, Advanced Metering, and Demand Response in Electricity Markets, 2002.

6.9 Assessing Economic Efficiency with a Social Cost-Benefit Analysis

The decision for a nationwide smart-metering roll-out should be based on sound economic analysis of social costs and benefits. As already laid out in chapter 2.4 Annex I of Directives 2009/72/EC and 2009/73/EC also stipulates that the implementation of smart metering could be subject to an economic assessment of all long-term costs and benefits. If such assessment results in a positive net benefit of smart metering deployment, EU Member States are obliged to ensure that electricity meters are rolled-out in a period of ten years and that a schedule for the roll-out of smart metering in the gas sector is decided upon.\textsuperscript{37} The major element of such economic assessment is a social cost-benefit analysis.

A cost-benefit analysis is a tool used to provide criteria for investment decision making. It is widely applied on the societal level as well as the company level. Whereas in the private sector appraisal of investments and financial analysis of company’s costs and benefits takes place against maximizing the company’s net benefits, the social cost-benefit analysis focuses on the overall long-term costs and benefits (including externalities, such as environmental impacts, and costs and benefits to third parties). This gives the social cost-benefit analysis a wider economic character with the objectives of maximizing welfare of a society (country or region) as a whole.

The external effects should also be included in the economic analysis. For example, energy savings as a result of smart metering deployment can bring substantial environmental benefits by avoiding emissions otherwise caused and by reducing the need to procure offsets needed for generation. If the environmental costs are internalized (i.e. included in the investment costs and in the operation and maintenance costs) eventual benefits will be automatically accounted for via the avoided costs. If this is not the case, they should be additionally quantified provided that sufficient information is available.

The social cost-benefit analysis applies dynamic investment appraisal methods. The most popular form applies the Net Present Value (NPV) approach. In this case the cost-benefit analysis seeks to select the project with the highest NPV, where the NPV is the sum of the discounted incremental costs and benefits over the project’s life time. Other approaches could be the calculation of the Internal Rate of Return on Investment or Dynamic Pay-Back.

The social cost-benefit analysis should study the impact on welfare of all parties affected by the project. The major objective of the economic cost-benefit analysis is to study the economic efficiency of the project, i.e. the welfare impact. If the total welfare is maximized (i.e. the project will bring maximal net benefits), then society as a whole will be better off as a result of the project. With smart

\textsuperscript{37} One of the main tasks of such economic assessment might be not only to identify costs and benefits but also which configuration, deployment strategy and schedule will provide the highest benefit.
metering for instance, the installation of the infrastructure is typically paid by the DSO or the party responsible for metering, whereas major benefits may be on the consumers’ side due to energy savings. Once smart metering deployment is assessed as positive overall, welfare distribution effects can be addressed separately.

For the assessment of smart metering deployment, a social cost-benefit analysis should include at least energy consumers, DSOs and energy suppliers. Depending on the market structure, separate metering companies might need to be included. Other than that the social cost-benefit analysis could be extended to TSOs, generators or the general government, or the consumer side can be split up into residential, small business and industrial customers. ERGEG recommends that for a social cost-benefit analysis of smart metering deployment, an extensive value chain covering all relevant stakeholders should be taken into account.38

Recent social cost-benefit studies on the deployment of smart metering assessed costs and benefits for final consumers, network operators, suppliers, industry and energy sector (PwC, Austria39), final consumers and industry players (Force Motrice/ATKearney, Hungary40) or households, metering companies, DSOs, suppliers, generators and the general government (KEMA, Germany41).

For social cost-benefit analyses discrete assumptions on input parameters are required. It is thus necessary to assess expected costs very carefully, e.g. for installing the metering and communication infrastructure, operation costs and stranded investments, and expected benefits, such as the amount of energy saved, the benefit from demand response and the savings associated with avoided manual meter readings, improved invoicing procedures and reduced fraud. Additional important input factors to consider for the model are the time horizon of the model and of course assumptions on the discounting rates and inflation.

To take into account the uncertain nature of many of the input parameters, a certain bandwidth of assumptions should be tested in sensitivity analysis. Furthermore, different model scenarios regarding deployment strategy, market model and deployment schedule must be defined and compared, in order to identify the option providing the highest net benefit.

38 ERGEG, Public Consultation Paper on Draft Guidelines of Good Practice on Regulatory Aspects of Smart Metering for Electricity and Gas, Ref: E10-RMF-23-03, Brussels, 10 June 2010
39 PriceWaterhouseCoopers, Studie zur Analyse der Kosten-Nutzen einer österreichweiten Einführung von Smart Metering, Juni 2010
40 Force Motrice, ATKearney, Assessment Smart Metering Models: The Case of Hungary, Improved Final Report, 18 June 2010
41 KEMA, Endenergieeinsparungen durch den Einsatz intelligenter Messverfahren (Smart Metering), Final Report, Bonn, June 2009
7. Conclusions

Smart metering is at the moment one of the ‘hot’ topics in the energy sector. In the European Union the Third Package boosted the discussion by requiring Member States to devise firm roll-out schedules if smart metering is assessed as economically positive. Smart metering can deliver a wide variety of benefits to the individual market parties and also to society as a whole. For electricity, a smart metering infrastructure is also the natural precursor for a smart grid. Smart grids will be required to cope with the major challenges network operation faces, resulting from changing generation and load patterns with the integration of distributed generation, renewables and novel loads (e.g. electric vehicles). However, smart metering comes at significant costs. Smart metering deployment should thus be subject to careful economic assessment using social cost-benefit analysis and if possible supported by results and evidences from representative pilot projects. The chosen roll-out in terms of technology, functional requirements and schedule should be the option that provides the highest net benefits.

This paper discusses the role of regulation in the smart metering deployment process. Regulation plays a major role in a smart metering roll-out. The regulatory authorities are the obvious parties to take up responsibility for the economic assessment and for devising a roll-out strategy, thus ensuring overall efficiency. Moreover, regulation needs to be carefully adjusted to the smart metering roll-out plans, firstly, to mitigate potential barriers to smart metering, and secondly, to create sufficient incentives for market parties to invest in and to use smart metering, thereby ensuring that prospected benefits can be realized. In particular, incorporating the efficient investment costs in the allowed revenue and the design of ‘new’ tariff schemes incentivizing consumers are essential to ensure maximal benefits from smart metering. In those countries where final consumption tariffs are still regulated, the regulator certainly has immediate influence on the promotion of such tariffs. But also in those countries where final consumption tariffs are not regulated, framework conditions regarding for instance the usage of standard load profiles need to be adjusted.

In order to avoid inefficiently high costs of a smart metering roll-out, a more gradual approach could be chosen, stretching the roll-out over time and allowing regional priorities to be set where considered necessary. Thus, stranded investment and peaking demand for resources can be reduced. However, costs and benefits of different approaches have to be assessed carefully during a comprehensive social cost-benefit analysis.

Smart metering is certainly an electricity topic but could also provide added value if applied to other utilities such as gas or district heat. An integrated and coordinated multi-utility approach when devising the deployment strategy could enable such extension to other utilities where an individual approach might fail due to the lack of a positive business case. Whereas a DSO led roll-out seems to be generally advantageous in a vertically integrated energy sector, a multi-utility approach might be better facilitated by a separate metering service provider.
Special attention should also be paid to standardization issues to ensure interoperability of hard- and software from different manufacturers, in order to avoid stranded investment and barriers to further development. Dealing with data security and integrity issues is necessary to avoid endangering public acceptance of smart metering.

Public acceptance and consumer education are crucial for successful smart metering deployment. In order to ensure success, the smart metering roll-out should be accompanied by informational campaigns designed to increase consumer’s awareness, acceptance and energy saving affinity.
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Appendix

UK
There has been discussion about the introduction of smart metering in the UK for several years. As of around 2005 there has been no longer been any real dissent on the question of whether smart metering for the residential sector should be deployed. In October 2008 the government announced the mandate of smart metering for the residential sector. This was followed by an announcement in December 2009 that 50 million smart gas and electricity meters are to be installed by 2020. Recently, in July 2010, the final plans of the government for smart metering deployment were published for consultation together with the most recent cost-benefit analysis.42

The proposed roll-out requires a full set of functionalities including the option to switch the meter to a prepayment scheme. Other noticeable functionalities are: (1) HAN communication via open standards and protocols, (2) real-time information provided on a connected in-home display, (3) load management capability, (4) remote disconnection and a communication capability with on-site microgeneration. The minimum information to be shown for the in-home display is also defined. The proposed roll-out scheme stipulates further that communication for smart metering is provided by a single company and to be used by all parties (central communications model) and that suppliers are responsible for the deployment of the metering devices themselves. The overall responsibility for the smart metering deployment is given to the Department of Energy and Climate Change (DECC), primarily working together with British regulator OFGEM but also coordinating with other involved parties.

The most recent cost-benefit analysis conducted by DECC results in a net benefit (NPV) of 7.2 billion GBP (best estimate, in central communications model) for domestic and smaller non-domestic customers over the next 21 years, mostly stemming from energy savings and cost savings in industry processes. A best estimate for total costs is 9.7 billion GBP; total benefits are estimated at 16.9 billion GBP. Broken down for the market parties the total consumer benefit for domestic and smaller non-domestic customers is given as 8.77 billion GBP, supplier benefits as 6.71 billion GBP and other benefits as 1.4 billion GBP.

Regarding data privacy, it has been stipulated that customers should be able to decide which information is used and by whom, except where data is required to fulfill regulated duties. The government acknowledges positive consumer engagement as crucial for success, and subsequently plans to implement programs to promote consumer knowledge and awareness.

Sweden

The Swedish system is characterized by very high electricity consumption per capita as electricity is also widely used for heating purposes. The average per capita consumption is 9,200 kWh per year. At the beginning of the decade metering became an important topic on the political agenda in Sweden, caused by increasing energy prices, power conservation, incomprehensible energy bills (which were inaccurate and did not correspond with the actual consumption), and the strong desire to have a correlation between energy costs and energy consumption.

In May 2002, the Swedish regulator performed a cost-benefit-analysis on the introduction of monthly reading of electricity meters, resulting in benefit estimations of about 60 million € per year. Total costs were estimated to be around 1 billion €.43 Thereafter it was decided that every user with an average annual energy consumption of more than 8,000 kWh should have their electricity meters read at least once a month by 2006. By the July 1, 2009, all meters were required to be read monthly. In practice with annual meter reading and large sparsely populated areas, this resulted in the deployment of smart metering. Smart metering (or in many cases more simple remote reading of hourly values) is now deployed all over the country. When deployment of remote meter reading started, some of the technologies currently available were not on the market at that time. Nowadays, DSOs typically deploy smart meters and also assess additional benefits from real smart metering. Around 10%-15% of the installed meters are in metering systems which are only capable of monthly remote meter reading. It is expected that these meters will be replaced significantly before the end of their economic lifetime. In some pilot projects the potential of real-time tariffs and new services is evaluated.

Interestingly, a comprehensive cost-benefit analysis for a national smart metering deployment never took place, only the benefits of monthly meter reading were assessed. The decision to go for an advanced metering system was taken by the DSOs individually; however it resulted in a more or less uniform approach all over the country. The metering sector is not liberalized, responsibility for metering lies with the DSOs. DSOs have also had to bear the costs of smart metering deployment so far, although recently the regulator had to grant increased network charges. There are no rules for third-party access to consumption data (e.g. by independent service providers) and there is no legal obligation for the interoperability of smart metering systems, or for exchangeability of meters.

Annex: United States Experience

The Annex was submitted on behalf of the National Association of Regulatory Utility Commissioners by:

Diane Ramthun  
Assistant General Counsel  
Wisconsin Public Service Commission

Sarah R. Thomas  
California Public Utilities Commission  
Legal Division

Disclaimer

This paper represents the views of Diane Ramthun, an attorney with the Wisconsin Public Service Commission, and Sarah R. Thomas, an attorney with the California Public Utilities Commission, and not the Commissions themselves, the Commissioners, or any other staff persons of the Commissions.
In the United States, about 65 million smart meters are projected to be deployed over the next five to seven years, covering about 50 percent of U.S. households by 2020. Large investor-owned utilities are conducting the majority of smart meter deployments within their respective state service territories, in projects that vary greatly in size, scope, cost, and functionality of the metering equipment. The American Reinvestment and Recovery Act of 2009 (ARRA) has made available millions of dollars of funding for smart meter deployments as part of its goal to jump-start the U.S. smart grid as a national priority. These federal stimulus funds, together with utility investment, are responsible for much of the smart meter deployment currently occurring in the U.S.

As a building block to the smart grid, state regulatory commissions want to encourage the deployment of smart meters, while ensuring that projects are in the public interest. Under their broad authority to regulate utilities, state regulatory commissions are establishing rules and guidance for utilities in deploying smart meters as well as other smart grid projects. For example, commissions in Texas and California have established minimum functionality requirements for smart meters and guidelines in the analysis of benefits/costs.

State regulatory commissions are also reviewing smart meter projects in the context of utilities seeking approval to make large scale installations, obtain cost recovery through rates, and impose new tariffs and consumer practices related to smart meters. The Public Service Commission of Maryland, for example, in a landmark decision reviewed a proposal for a large scale deployment of smart meters by a utility and initially rejected it, in part because the Commission disagreed with the proposed cost recovery method.

Across states, common regulatory issues concerning the smart meter deployments are emerging. State commissions have raised concerns about cost/benefit, cost recovery, technology, consumer protection, privacy, cyber security, health effects, and public interest aspects of the projects. Many of these issues are evolving as the complexities and effects of smart meter deployments become better known and understood. Given the rapidly developing smart meter and smart grid technology, it can be expected, that in the future, new regulatory issues will emerge and some of the current ones will resolve as deployments continue and the smart grid is developed.

State regulatory commissions vary in their approach to resolving smart meter deployment issues, in part because of the uniqueness of individual projects and differences in socioeconomic conditions and weather climate among states. The discussion below identifies key issues that have been raised by state regulatory commissions in recent smart meter deployments in the U.S.

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44 Institute for Electric Efficiency, September 2010 Update, Edisonfoundation.net/iee/ (last visited January 20, 2011). For the purposes of this reference, smart meters are defined as advanced meters that allow for two-way communication and real-time electricity consumption information.

45 American Recovery and Reinvestment Act, Pub.L. No. 111-5 (2009) (Title IV – Energy and Water Development, Dept. of Energy, “Electricity Delivery and Energy Reliability” states that “funds shall be available for expenses necessary for electricity and energy reliability activities to modernize the electric grid, to include demand responsive equipment, enhance security and reliability of the energy infrastructure, energy storage research, development, demonstration and deployment…”)


48 In the Matter of the Application of Baltimore Gas & Electric Co. for Authorization to Deploy a Smart Grid Initiative and to Establish a Surcharge for the Recovery of Cost, Order No. 83410 (Md. PSC June 21, 2010), http://webapp.psc.state.md.us/Intranet/Maillog/orders_new.cfm.
Regulatory Issues in the United States

I. Cost/Benefit: State regulatory commissions are questioning whether the costs of smart meter deployments outweigh the benefits to consumers, particularly during the current recession, and have scaled down or rejected proposed projects for excessive costs.

- In 2009 and 2010, public service commissions in Maryland, Hawaii, and Indiana required large smart meter projects to be scaled down in their respective states.

II. Consumer Protection Issues: State regulatory commissions are addressing a range of consumer protection issues raised in conjunction with the installation and operation of smart meters, as well as the related tariffs and consumer practices of utilities. Areas of particular concern are:

- Whether consumers will adopt new, related technologies such as home area networks (HAN) that are necessary for consumers to take advantage of the functionalities of smart meters, but also are expensive and require education to use.
- Protection of low income, elderly and disabled consumers who may not have the means or ability to purchase the related home area network technology to enable them access to their usage data and to use time-of-day rates.
- Consumer privacy with respect to data collected by smart meters that can be transmitted to third parties. (This issue is discussed in more detail below.)
- Consumer safety and security because smart meters may reveal personal information to those outside the home, such as when the occupants are away or present, what appliances they own, and what medications they use.
- Dynamic rate designs, such as Time of Use rates, that allow consumers to take advantage of the smart meter’s technology, but may be disadvantageous to those consumers who cannot shift energy usage to off-peak times and take advantage of off-peak rates. Such customers may therefore end up with higher energy bills that they cannot afford.
- Remote disconnect functionalities of smart meters may allow utilities to more quickly shut off power for customers with small unpaid bills than a utility would otherwise disconnect with traditional meters.

III. Cost Recovery: State regulatory commissions are scrutinizing how utilities propose to recover smart meter deployment costs from ratepayers and have allowed different methods of recovery, ranging from traditional ratemaking to surcharges and riders for upfront recoveries.

- In 2010, the Maryland Public Service Commission found a proposed surcharge would unfairly impose the entire risk of the smart meter project on ratepayers. The Commission subsequently approved the project when the utility proposed to recover costs by traditional ratemaking, which would the commission to consider whether the investment was prudent and in the public interest.

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49 See, footnote 48.
• In 2009, the Illinois Commerce Commission approved a “smart grid” rider intended to recover a utility’s costs in a smart meter pilot project. In 2010, however, an Illinois appellate court overturned this determination and rejected the rider as improper, single issue rate-making.53

• In 2007, the Texas Public Utility Commission adopted a rule which allows smart meter deployments that meet minimum functionality standards to qualify for a cost recovery surcharge.54

IV. Early Obsolescence of Recently Installed Smart Meters: State regulatory commissions are concerned about how to account for rapidly changing smart technology, particularly the communication function of the smart meter which can render expensive smart meters obsolete within a few years, unlike traditional meters which are very long lasting. This could result in stranded costs and raises the question of who pays for early obsolescence, the ratepayer or the utility.55

• In California, thousands of smart meters recently installed became obsolete as smart technology evolved and had to be prematurely retired. Over ratepayers’ objections, the California Public Service Commission granted the utility funding to upgrade the obsolete smart meters.56

V. Accuracy and Reliability of Smart Meters: State regulatory commissions have investigated consumer complaints that their energy bills were increasing as a result of inaccurate smart meters.

• In 2010, the Public Utility Commission of Texas, ordered an independent study of the accuracy of recently installed smart meters in response to consumer complaints. The Commission reported on August 2, 2010, that the study results showed smart meters gave more accurate readings than the traditional meters they replaced. (99.96% of meters were accurate compared to 96% of traditional meters under American National Standards Institute standards.)57

• By the fall of 2009, the California Public Utilities Commission had received over 600 smart meter consumer complaints about unexpectedly high bills and allegations that the new electric smart meters were not accurately recording electric usage. The Commission therefore ordered a study of the issue; the study concluded that the meters were generally functioning properly but that customers had experienced unexpectedly high bills due to many factors. Those factors included the following, some related to and others not related to utility conduct or the meters themselves:
  o A heat wave at the time of deployment.
  o Other rate increases at the same time.
  o Electromechanical meter degradation.

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55 See, for example, In the Matter of the Application of Baltimore Gas & Electric Co. for Authorization To Deploy A Smart Grid Initiative and To Establish A Surcharge for the Recovery Of Cost, Order No. 83410 (Md. PSC June 21, 2010), http://webapp.psc.state.md.us/Intranet/Maillog/orders_new.cfm .
56 Application of PG & E for Authority to Increase Revenue Requirements to Recover the Costs to Upgrade its SmartMeter TM Program, 272 P.U.R.4th 1.
o Incorrectly applied rates that were based upon historical premise assumptions.

o Utility processes that failed to address customer concerns associated with the new equipment and usage changes.

o Utility billing quality control that was not stringent enough, resulting in multiple bill cancelations and re-billings that were confusing to customers.\textsuperscript{58}

VI. Consumer Privacy, Safety and Security: At both the state and federal level in the U.S., regulators are considering how to protect the privacy of consumers who have smart meters and home area networks at their homes. Key concerns include the following:

• Smart meters can allow persons outside a home to determine if the home is occupied, creating burglary and other security risks.

• Smart meters and wireless home area network functions can allow persons outside a home to determine what appliances, medications, and other objects are inside the home.

• Data about personal energy usage can be sold to marketers or packaged with other data to create detailed portraits of the habits, lifestyle, purchasing decisions, and other behavior of the users of a home area network or smart meter.

VII. Inter-operability and Cyber-Security Risks of Smart Meter Technology: Large-scale deployments of smart meters are occurring before inter-operability and cyber-security risks have been addressed by government and the industry. These risks carry the potential to become major problems affecting all aspects of the smart grid from transmission systems to end-users’ home area networks. Standards addressing these risks are under development by the National Institute of Standards and Technology (NIST) and will ultimately be reviewed and implemented by federal regulators, such as the Federal Energy Regulatory Commission (FERC).\textsuperscript{59} Regulatory concerns include the risk that a third party could shut down the power grid or individual power plants; individual or large-scale theft of electricity; and individual or large-scale disconnection of customers.

Conclusion

In the United States, state regulatory commissions are encouraging and guiding smart meter deployments, while also regulating them in order to protect the public interest. The newness and complexity of smart meter deployments present challenges for state regulatory commissions because of consumer protection and public interest concerns. As smart meters will be deployed on an even larger scale in upcoming years, it can be expected that state regulatory commissions will work proactively to resolve issues and address new ones as they develop.


For copies of this publication, please contact Erin Skootsky (eskootsky@naruc.org) or Bevan Flansburg (bflansburg@naruc.org).