European Smart Metering Guide

Energy Efficiency and the Customer

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Notes on the 2009 Edition

The opportunity has been taken to revise the text to improve readability and correct any errors that had been noted in the previous edition. Chapter 13 “Marketing smart metering services” has been added. Chapter 6 “Smart Metering and the smart grid” has been rewritten and is now focused on smart metering features for the Smart Grid. In general, where possible the focus of the Guide has been shifted more fully onto energy efficiency and sustainability and less on the ‘mechanics’ of smart metering. The Guide has also been updated to reflect changes that took place up to October 2008. These include the introduction of the Batteries and Accumulators Directive, the release of the ZigBee energy profile, the release of a number of new energy display devices and general progress in the area of standards.

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Executive summary

Smart metering is being introduced in many countries across Europe. As well as facilitating the business processes of utilities, smart metering can also provide final customers with detailed information on their domestic energy consumption. This information includes data on how much gas and electricity they are consuming, how much it is costing them and what impact their consumption is having on greenhouse gas emissions. It is generally believed that this information can be used by customers to reduce their energy consumption. However, this is a new topic and there is little experience of using smart metering to support energy efficiency. This Guide has been produced to collect best practice as it is currently understood and advise those charged with implementing smart metering. As such it is a work in progress and all of the chapters will be the subject of future updates. These will capture both the increase in the understanding of the topic and the new applications that smart metering may catalyse.

Europe faces daunting challenges in reducing its energy consumption and mitigating the impact of climate change. Smart metering can contribute towards these objectives and it is recommended that utilities and other stakeholders should consider the various benefits that smart metering can deliver including:

- enabling services that improve energy efficiency and help to save energy
- enhancing business efficiency and service performance of distribution system operators, energy retailers, energy service providers and energy final customers
- avoiding investments in networks and generation

Analysis of trials of smart metering presented in Chapter 3 leads to the following guidance about energy feedback:

- Consumers need to be able to see instantaneously and continuously what is happening to their consumption, without having to switch on an optional in-home feedback device first;
- Direct feedback promises to be more effective than indirect feedback;
- Feedback promises to be more effective when accompanied with goal setting;
- Historic feedback promises to be more effective than comparative or normative feedback;
- Direct displays in combination with better billing promises to be a more preferred way of communication for consumers than feedback through an indirect (delayed) personalized web page
- The internet promises to provide useful additional feedback through incorporation of further analysis and advice on a longer term basis

For smart metering, it is necessary to be able to communicate remotely with the meter. This is enabled by a Wide Area Network (WAN). To support the introduction of new products and

services related to energy services and energy efficiency the design of the WAN should allow for future growth in communication performance requirements (such as data rates, availability and speed of response). To allow smart meters to integrate with smart homes control devices and customer owned energy management software meters should contain a bidirectional communication link. This communication should be supported by the adoption of standard interfaces and data communications protocols. Because smart meters record sensitive personal information, provide data for billing and provide access to critical networks the security of the system must be managed appropriately. It must be ensured that only approved parties can access the meter data and communications networks. (Chapter 4)

The use of smart metering to promote sustainability applies to all utilities, including gas, heat and water. To allow these to benefit from smart metering it is recommended that multi-utility smart meter systems should be implemented. This should be supported with an expandable data standard that can accommodate all of the utilities used. Regulators should consider how best to allow access to all market participants so that smart metering can support a liberalised market model. For district heating companies and governments, before installing smart metering, the first step should be to improve the thermal efficiency of the system, networks and properties. Smart metering of heat supplies does not fit well with previous industry practice but it should be applied to thermal nodes and heat substation and future installations should be smart meter enabled... For District heating and natural gas companies there is a need to develop complimentary services that can be delivered with the smart metering system. Careful consideration should be given where multiple utilities are displayed in the same location to ensure that appropriate environmental messages are conveyed. (Chapter 5)

Huge investments are needed in the power sector in the upcoming decade in Europe due to the increasing energy demand, ageing generation facilities and ageing transmission and distribution infrastructure. Simultaneously the electricity grid will have to be adapted to a further increase in the share of both Renewable Energy Sources (RES) and Distributed Generation (DG). Because of this the European distribution grids are expected to develop into a Smart Grid. Utilities should investigate to what extent the ICT systems for smart metering can be combined with those for the Smart Grid. Basic smart metering features for the Smart Grid include the support for dynamic pricing and for two-way communication with a Home Area Network (HAN). (Chapter 6)

The link between demand response and smart metering (DR) is explored in greater detail in Chapter 7. DR can be defined as the voluntary reaction by the final customer to a price signal, e.g. delaying electricity demand for an hour or two to avoid an extreme price peak. When preparing the roll out of smart meters, the relevant design features related to demand response should be included in the meter requirements and the costs and benefits associated with DR included in the financial analysis. The design features include the time resolution of the metered values (days, hours, quarters or minutes) and the feedback and communication possibilities.

Both smart homes and smart meters are promoted for the energy savings they can bring about in the home. Although they can both work independently, it is clear that combined they may provide even greater energy efficiency benefits. However, agreement must be reached on standard interfaces between the systems if this is to become widespread. (Chapter 8)

The introduction of smart metering will provide a dedicated gateway to the final customers' home. This will allow the energy retailer and energy service companies to offer additional energy related services that may benefit both final customers and the utilities. However, the introduction of smart metering to households and small-size businesses requires concerted action from all the market players in order that the potential benefits are harnessed to their full potential. Unless such a coordinated approach is taken, interested parties, such as utilities, may be exposed to costs without a corresponding counter value. Therefore, any plan for smart metering introduction should be designed based on a detailed cost-benefit analysis to avoid or diminish potential negative financial impacts. If a positive decision is taken, it should be accompanied by proper promotion activities directed at final consumers to explain why a smart meter is beneficial, what functionalities it will bring, and how it can be beneficial (e.g. to lower the present energy consumption and energy costs and improve comfort). (Chapter 9)

A key challenge facing the smart metering industry is that previous trials have given mixed results with regard to the energy savings. It is also becoming clear that it is not a simple matter to conduct a trial that gives an accurate forecast of the savings that will be achieved in a mass roll out. Further, the potential for energy savings can be expected to be different from one final customer segment to another and from one country to another and depending to how the trial is conducted. It follows that the lessons learnt in carrying out trials should be captured and shared as best (or not best) practice and a common methodology developed that gives reliable results that can be compared with those from other trials. Chapter 10 sets out guidelines on how to develop clearly efficient designs for such field tests. Key issues are that there must be a control group, samples must be sufficiently large to allow sub groups to be identified and that the trial groups should be surveyed so that factors that might disturb the results can be corrected.

Due to the role that energy plays in commerce and society it is inevitable that any significant change, such as the introduction of smart metering, will be the subject of regulation and the interest of governments and the European Commission. It is important to identify an optimum detailing level for the Regulation and this is the subject of Chapter 11. Poor, overly complex and unpredictable regulation will have negative impacts on the implementation of smart metering and reduce expected benefits. Regulators must consider the need to provide for the final customer to have access to meter data and to control the use of data by those other parties who have access to the data. Definition of common functional requirements for smart metering will increase the benefits both for utilities and for society as a whole. These functionalities should be coordinated with other relevant Authorities, for example, the Office of Weights and Measures.

The issue of stranded assets arising from smart meter roll outs must be considered by Regulators who should seek solutions that are fair to utilities and customers.

Utility metering is currently governed by the Measuring Instruments Directive and associated harmonised standards. The progression of smart metering will undoubtedly depend on the development of new standards to deal with the new functionalities introduced and to provide interoperability. Smart meters will introduce new data items and data flows as well as new business processes, such as dynamic tariffs, multi utility data flows, pre-payment options, whilst also making available detailed final customer usage data and distribution system performance. Chapter 12 takes a broad look at the issue of standardisation and how this can assist (or delay) the introduction of smart metering. Specific requirements are identified for the support of the energy efficiency aspects of smart metering. There should be an agreement on common minimum functionality and interoperability regarding provisioning of feedback from smart metering systems and European stakeholders should begin investigating the feasibility of adopting existing standards or developing new standards for use across Europe. These standards would need to cover physical and data aspects and meet the needs of all European member states. As much as possible, the standards should allow freedom to innovate smart metering systems and feedback techniques. Data standards should be expandable to allow the inclusion of entities such as those required to show environmental impact; for instance carbon equivalent (e.g. kg CO_2/kWh) of the energy stream. Physical and data standards should be agreed for local communications with meters. These should enable non-utility devices and systems to access meter data. Standards should allow the control of what data can be made available by the meter and access to the data.

In the final chapter of the Guide (Chapter 13) guidance is provided on how smart metering should be introduced to final customers. The attitude of the general public to smart metering can be crucial to its impact on energy consumption. A thorough survey of customers' attitudes should be conducted to inform both the design of the smart metering scheme and its introduction. It is possible for the public to have a negative attitude and these attitudes need to be anticipated and negated. Cooperation between the utilities and consumer bodies and energy agencies can assist in promoting a positive attitude.

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Contents

Abbreviations

Abbreviation	**Whole term**
AMI	Advanced Metering Infrastructure
AMM	Advanced Metering Management
AMR	Automatic Meter Reading
ANSI	American National Standards Institute
CEE	Central and East European countries
CENELEC	Comité Européen de Normalisation Electrotechnique (European Committee for Electrotechnical Standardization)
CHP	Combined Heat and Power plants
DER	Distributed Energy Resource
DG	Dispersed Generation
DH	District Heating
DR	Demand Response
DSO	Distribution System Operator
EE	Energy Efficiency
EEC	Energy Efficiency Credit (Energy Efficiency Commitment UK)
EEI	Energy Efficiency Improvement
ER	Energy Retailer
ERGEG	European Regulators’ Group for Electricity and Gas
ESCO	Energy service company
ESD	EU Energy Services Directive
ESC	Energy Savings Certificate
ESMA	European Smart Metering Alliance
ETSO	Association of European Transmission System Operators
EU	European Union
EUMF	End Use Monitoring and Feedback
HAN	Home Area Network
ICT	Information and Communication Technology
ISO	International Organization for Standardization
LAN	Local Area Network
MAP	Meter Asset Provider
MID	Metering Instruments Directive

MO(P)	Meter Operator
MRT	Multi-rate tariffs
NAP	National Action Plan
PLC	Power Line Communications
PPM	Pre-payment metering
RES	Renewable Energy Source
SO	System Operator
TSO	Transmission System Operator
WAN	Wide Area Network

1. Introduction

Utility metering is undergoing a revolution as long established mechanical and electromechanical meters are replaced by electronic meters. These electronic meters, combined with low cost communications and enterprise software, are enabling a wholly new approach to metering. This is referred to as ‘smart metering’ and it is the subject of intense interest from utilities and others around the world. One major benefit of smart metering is the ability to give customers accurate and timely information about their energy usage, which has been shown in trials to allow them to reduce their energy consumption. Smart metering can also enable more complex time of use tariffs so that system demands can be reduced. It must be understood though, that smart metering does not automatically provide customers with energy usage information and trials show varied results depending on how the information is presented. Energy feedback is a relatively new topic and the subject of growing interest and research. This Guide has been written, and ESMA set up, to provide advice on how to make smart metering an effective tool for energy efficiency.

This Guide has been written to provide advice to those developing and implementing smart metering systems, especially for those who want to use it to reduce energy consumption. Other readers should find it a useful guide to the exciting new topic of customer feedback.

1.1. Smart metering – scope and challenges

This report focuses on the promotion of Energy Efficiency of Energy Customers in relation to Smart Metering. In the utility world several definitions of Smart Metering are used, depending on which of the possible services are included or not. Within the context of this report the following definition of ‘smart metering’ is used [Koponen 2007]:

Smart metering has the following features:

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

‘Smart metering’ has received more and more attention within the utility sector around the world over the past years. This is due to a mix of factors including increasing technological possibilities, decreasing costs, and the desire for utilities to improve their services.

Another driving factor for smart metering - especially in Europe - is the increasing attention from governments towards energy efficiency. In Europe, through the Energy End Use Efficiency and Energy Services Directive [ESD], the European Commission has set requirements for EU Member States for the provision of energy consumption information to final customers from their meters [ESD 2006]. Article 13 of the ESD specifically refers to metering. The text of Article 13 is given below. In Italy and parts of Sweden and Finland advanced metering has already been installed [Togeby 2008].

Article 13 of the ESD Metering and informative billing of energy consumption

1. Member States shall ensure that, in so far as it is technically possible, financially reasonable and proportionate in relation to the potential energy savings, final customers for electricity, natural gas, district heating and/or cooling and domestic hot water 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.

When an existing meter is replaced, such competitively priced individual meters shall always be provided, unless this is technically impossible or not cost-effective in relation to the estimated potential savings in the long term. When a new connection is made in a new building or a building undergoes major renovations, as set out in Directive 2002/91/EC, such competitively priced individual meters shall always be provided.

2. Member States shall ensure that, where appropriate, billing performed by energy distributors, distribution system operators and retail energy sales companies is based on actual energy consumption, and is presented in clear and understandable terms. Appropriate information shall be made available with the bill to provide final customers with a comprehensive account of current energy costs. Billing on the basis of actual consumption shall be performed frequently enough to enable customers to regulate their own energy consumption.

3. Member States shall ensure that, where appropriate, the following information is made available to final customers in clear and understandable terms by energy distributors, distribution system operators or retail energy sales companies in or with their bills, contracts, transactions, and/or receipts at distribution stations:
(a) current actual prices and actual consumption of energy;
(b) comparisons of the final customer's current energy consumption with consumption for the same period in the previous year, preferably in graphic form;
(c) wherever possible and useful, comparisons with an average normalised or benchmarked user of energy in the same user category;
(d) contact information for consumers’ organisations, energy agencies or similar bodies, including website addresses, from which information may be obtained on available energy efficiency improvement measures, comparative end-user profiles and/or objective technical specifications for energy-using equipment.

Smart metering schemes are being developed in many countries across Europe, including the Netherlands, United Kingdom, France, Germany, Spain, Portugal, Irish Republic, Norway and Denmark.

The implementation of smart metering systems that reduce energy consumption is not simple for a number of reasons. The main reasons are:

- Although trials seeking to establish the energy saving benefits of smart metering have yielded promising results, the trials have been carried out in different ways so that firm conclusions cannot be drawn. It is also clear that final customer reaction depends on the way that the information is presented to them and the proposition they are offered by the Energy Retailer. Smart metering has given best results in combination with other methods and not alone.

- Smart metering systems provide a number of benefits beyond customer information and different parties receive these benefits. This creates the need to share the costs of implementing smart metering in proportion to the benefits received. This becomes more of a challenge as energy markets are broken up and more parties are involved.

- Article 13 of the ESD offers a wide range of interpretations, where some of the key parameters (especially “estimated potential savings”) needed to make these judgements are not available or accepted by all parties. This lack of certainty leads to a cautious interpretation of the Directive that may fail to deliver the full energy efficiency benefits of smart metering.

Smart metering is a recent development and there is only limited experience with it. Consequently, there is a high degree of perceived risk in its implementation.

For the purposes of the ESMA project, the main feature of smart metering is the possibility of providing final customers with more information on their energy usage. Support for this claim comes from a series of trials of smart metering that have been carried out and these suggest that final customers can save between 10% and 5% of their energy consumption when provided with such information. As approximately 40% of the European Member States energy consumption passes through the meters covered by the ESD, the potential for improved energy utilisation is substantial and explains the widespread interest in smart metering.

A further claim for smart metering is its focus on total energy consumption levels. There is growing focus on reducing total energy demand rather than improving the efficiency of individual devices and appliances. This shift follows concerns that, even with more efficient appliances, it is possible to see consumption go up as final customers make more use of the appliances or purchase larger ones. Smart metering, by providing a direct view of their total consumption levels, allows final customers to understand and reduce their total consumption.

1.2. Purpose of this guide

Smart metering can provide the foundations for a radically different approach to energy reduction schemes. However, the implementation of smart metering is a complex undertaking and its success depends on getting many factors right, from technology choice to how the information is presented to final customers. Making the expected reduction in energy consumption depends on achieving a positive reaction from final customers. Maintaining and increasing these savings will need the engagement of Energy Retailers, energy agencies and others.

This Guide has been produced to bring together the lessons learnt from smart metering systems and trials, targeted on the promotion of End Use Energy Efficiency. The aim is to assist those groups implementing smart metering for this purpose (possibly among others) or considering it and to maximise the benefits arising from those implementations. .

The main target audience for the Guide are utilities, ESCO's and service providers across Europe. In most countries these are the parties investing in the smart metering systems and providing the smart metering services. In addition to these, governments, regulators, consumer bodies and energy agencies, as well as suppliers and system integrators, might also find valuable information in the Guide.

As the subtitle indicates, the focus of this Guide is on the application of smart metering for improving energy efficiency. Making the expected reduction in energy consumption depends on achieving a positive reaction from final customers. In general, the successful provision of smart metering services is highly dependent on the right involvement of the energy final customer.

This guide is not a ready-to-go manual for the installation of a specific type of smart metering system. Rather, the authors have tried to give the reader an insight into some of the complexities of the whole implementation process of smart metering systems. Also the guide is impartial regarding different technologies, unless there is strong evidence available.
As experiences with smart metering are accumulating quite rapidly, this Guide will be updated yearly to keep up with developments. To assist in this process of updating, readers are invited to send any comments or remarks to the authors.[1]

1.3. About the European Smart Metering Alliance (ESMA)

This Guide is produced by the Project Team of the European Smart Metering Alliance (ESMA). ESMA is an alliance of companies and organisations for the advancement of smart metering in Europe. ESMA is working to develop best practice in smart metering so as to deliver the best energy efficiency benefits. It has been formed by a number of interested organisations from across Europe - from academics to utilities and energy agencies - with partial funding from the European Union's Intelligent Energy for Europe programme.

ESMA consists of a Project Team and an Alliance. The ESMA Project Team is responsible for producing a number of European-wide reports on smart metering, including this Guide. The Alliance works together closely with the ESMA Project Team, and has been involved in commenting on draft versions of this Guide.

Membership of the alliance is open to all organisations involved in smart metering at a nominal fee of € 500 per annum[2]. Members of the Alliance have the benefits of being informed of smart metering developments throughout Europe; being able to play an active part in shaping the activities of the Alliance; and having access to all of the project deliverables. More information about the European Smart Metering Alliance is on the website: www.esma-home.eu

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[1] Please send your remarks to John Parsons (BEAMA) at JohnP@beama.org.ukn.nl

[2] Non-corporate organisations can join the Alliance for free. Please contact esma@beama.org.uk for details.

2. Why smart metering?

There are many reasons for introducing smart metering, the most important of which, for this Guide, is its potential for promoting energy efficiency and greater sustainability. This chapter briefly examines the environmental, commercial and regulatory context within which smart metering is being developed, sets out the primary benefits that might be achieved by a successful implementation of smart metering and highlights those specific benefits that meet the objectives of this Guide.

2.1. Context of smart metering

Europe faces daunting challenges in reducing its energy consumption and mitigating the impact of climate change. One measure taken in Europe has been the introduction of The Energy End Use Efficiency and Energy Services Directive (ESD) [ESD 2006] which has been implemented by Member States during 2008. This requires all member states to reduce their energy consumption by 9% over 9 years. Article 13 of the Directive sets European Member States minimum requirements for the provision of energy consumption information to final customers from their meters. This has provoked great interest amongst governments, utilities and regulators in the introduction of smart metering as the preferred means of providing this information and a number of countries are pressing ahead with implementing smart metering.

Although the ESD is the major reason for the current interest in smart metering, there are a number of other European Directives that are relevant. These are the Services Directive [SD 2006], the Measuring instruments Directive [MID 2006], the Energy Performance in Buildings Directive [EPBD 2002] and the Commission's third legislative package for Electricity & Gas markets, September 2007 [EC 2007].

Smart metering refers to a whole range of new functionalities which have been made available by the introduction of electronic utility meters, low cost communications and enterprise software. Smart metering allows utilities to remotely read and manage meters, communicate with final customers and provide final customers with accurate and detailed energy usage information. The multiple possibilities of smart metering have led to a large number of different definitions of smart metering. ESMA has adopted the definition as given in Chapter 1.

- For the purposes of ESMA the main feature of smart metering is the facility to support energy savings through, for example, the provision of more information to final customers.
- The reason for this is that a series of smart metering trials suggest that final customers can save up to 10% of their energy consumption when provided with such information [Van Elburg 2007]. As approximately 40% of the European Member States energy consumption passes through the meters covered by the ESD, the potential for improved energy utilisation are substantial and explain the widespread interest in smart metering.
- Additionally, there is increasing interest in the reduction of energy demand as an objective rather than aiming for improved energy efficiency of individual devices and appliances. This shift follows concern that, even with more efficient appliances, it is possible to see consumption go up as final customers make more use of them or buy larger ones. Smart metering, by

providing a direct view of total consumption levels, allows final customers to understand and reduce their total consumption.

2.2. Advantages and costs of smart metering

Although the focus of this Guide is on energy efficiency and demand reduction, a full listing of the various benefits of smart metering is given in the Table below. These benefits are instrumental in formulating the process of implementing smart metering. Where this Guide deals with a benefit in more depth, this is indicated in the text. Those benefits directly benefiting energy efficiency are highlighted.

Table 2-1 Benefits of smart metering

Benefit	**Beneficiaries**				
	Customers	Energy Retailers	DSO	Government/Regulator	Energy agencies
Advantages of smart metering					
Network operations					
By providing information from every supply point the DSO will receive greatly increased levels of monitoring of the distribution system. This information can be used to improve their operation of the network and investment decisions related to system upgrades.			✓		
Meter and billing operations					
Remote collection of meter data should reduce the cost of data collection, eliminate estimated bills and provide accurate data for usage information on bills.	✓	✓	✓		
Linkage of different utility meters (such as electricity, gas, heat and water) further reducing the costs. **See Chapter 5 “Smart metering systems – multi-utility issues.**		✓			
Smart metering can reduce theft and increase revenues for Energy Retailers. Identification of locations where fraud levels are high is possible. Realising this benefit, however, depends on careful implementation of smart metering systems and higher specification meters as fewer site visits can leave meters vulnerable to interference. This is a benefit to honest customers as well as the Energy Retailers and DSO.	✓	✓	✓		
Remote management of meters will allow meter operators to		✓	✓		

Benefit	**Beneficiaries**				
	Customers	Energy Retailers	DSO	Government/Regulator	Energy agencies
avoid physically visiting meters and eliminate problems associated with gaining access to meters. It can also help with remote switch-on/off functionality to reduce safety risks and energy consumption on unused premises.					
Demand management and system operation					
Smart meter systems can be used to reduce the final customer load when networks or generation capacity is approached, reducing the cost of energy supply and improving its energy efficiency. **See Chapter 7 “Smart metering services for demand response”**.		✓	✓	✓	
Energy efficiency, embedded generation and renewables					
Smart meters will provide final customers with much more energy usage information, either on their bills, via the internet or directly within their homes, or a combination of all of these. Current expectations are that final customers will respond to this information by reducing their consumption by between 10% and 5% for in house displays. This should reduce their energy costs although this will depend on the details of their supply contract. **See Chapter 3 “The customer and smart metering”**.	✓	✓		✓	✓
Smart metering will support embedded generation and the integration of renewable power generation. Signals from the smart metering system can also be used to control energy management processes within the property, allowing further cost reduction. **See Chapter 6.2 “Smart metering and the Smart Grid”**.	✓	✓	✓	✓	✓
Smart meters will support dynamic tariffs that may be required to improve the utilisation of less predictable wind and solar energy resources. **See Chapter 6.2 “Smart metering and the Smart Grid”**		✓	✓	✓	
Smart meter components and infrastructure can be linked to other energy savings schemes such as White Certificates. **See Chapter 9 “The utility and smart metering”**.	✓	✓			

Benefit	**Beneficiaries**				
	Customers	Energy Retailers	DSO	Government/Regulator	Energy agencies
Smart metering will create an opportunity for energy efficiency agencies and other groups promoting energy demand reduction to devise enhanced energy savings measures based on the use of smart meters (for example, providing immediate feedback on savings resulting from the use of low energy light bulbs). **See Chapter 9 “The utility and smart metering”.**		✓		✓	✓
Market operation					
Smart meters may provide improved and faster processes for final customer switching between Energy Retailers. This would support market liberalisation.	✓	✓		✓	
Smart metering can enable demand response that is necessary for efficient and secure operation of the electricity markets and other energy markets.	✓	✓		✓	
Smart meters offer the possibility of reducing the capacity of the electricity/gas connection which may also have benefits for lower income classes as an alternative to disconnection.	✓	✓			
Smart metering can support pre-payment contract options making pre-payment more attractive and less costly for final customers. **See Chapter 4 “Smart metering systems – technical options”**.	✓	✓			✓

Table 2-1 Costs of smart metering

Cost	**Party**				
Investment cost					
It is clear that the use of smart meters will be associated with a number of higher costs, ranging from the capital cost of the meters, communications costs (capital and operating costs) to possibly higher maintenance costs. These greater costs will be accompanied by the reduced costs listed above and their balance will vary from implementation to implementation. Further information on this can be found in ESMA Work Package 3 “Financial Toolkit” [Parsons 2008A]. What can be said is that the implementation of smart metering, because of	✓	✓	✓	✓	

the large number of meters involved, will typically represent a very large financial investment that must be fully and carefully justified.					
Energy consumption					
Smart metering systems are likely to consume more power than conventional metering. Any analysis of the energy saving benefits of smart metering should include a comparison of the energy consumption of the conventional and smart systems. If the smart metering system consumes more this additional load must be deducted from the final customer energy savings. Based on current technology and largely arising from the communications function, potentially this could raise residential electricity demand by 0.5%. Advances in low power electronics will ameliorate this disadvantage over time. This issue is dealt with in more detail in D2 Impact of Smart Metering [Parsons 2008B].	✓	✓	✓	✓	✓
Security					
Smart meter systems are vulnerable to hacking attempts as they are widely accessible for extended periods and control large financial values. There will be a cost implication to ensuring their current and future security.	✓	✓	✓	✓	

2.3. Progress towards smart metering

The benefits of smart metering have been recognised within the ESD and by member states. Advanced metering has already been installed in Italy and parts of Sweden. Schemes are being developed in the Netherlands, United Kingdom, France, Germany, Spain, Portugal, Irish Republic, Finland, Norway, Denmark [Togeby, 2008]. Trials of the technology are underway across Europe, including major trials of 300,000 homes in France and 43,000 homes in the UK. The provision of energy feedback information varies considerably between the different schemes, with some providing feedback via more frequent and accurate bills and others making information available on the meter or via an internet link. The ESMA Annual Report 2008 [ESMA 2009] contains a detailed listing of all the schemes that we have been able to discover. Outside of Europe there is also progress in smart metering, principally in the US, Canada and Australia. A good report on the cost benefit analysis of smart metering and the recommended functionality is available from Australia [NERA 2008].

2.4. Recommendations

- Regulators should require that all utilities introducing smart metering include a statement in their proposals on how they will use the smart metering to enable and support services that improve energy efficiency and help to save energy.

- Both costs and benefits of smart metering systems are highly dependent upon national and local circumstances and upon specific characteristics of final customer segments. A proper evaluation of the costs and benefits of introducing smart metering should therefore be done per country and per final customer segment.

- Before introducing Smart Metering for reasons of energy efficiency, a full energy analysis should be made of the system to be used. This energy analysis should not only take into account the expected increases in energy efficiency at the final customer side, but also the increase in energy consumption through the deployment of the smart metering system (including the stand-by consumption of the ICT equipment).

2.5. References

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3. Smart metering and customer feedback

This chapter identifies the current understanding of the most effective consumer feedback techniques that can be considered to favour the implementation of smart meters for lower costs and higher benefits. This is based on the conclusions of a broad sample of the latest international research findings and recent experiments into the information aspects of smart metering, containing both positive as well as negative experiences [Elburg 2007]. The purpose of this chapter is to lead the reader to some clear principles for effective customer feedback.

3.1. Benefits for consumers

Traditionally, utility meter readings are not easily accessible to consumers. The information is displayed in kWh, often shown as a cumulative total. And the consumer cannot access historical or instantaneous information. Even billing is often based on estimates without useful historical information. Except for countries where self-reading is common and meters are freely accessible to the consumers, the meters are often put close to where the electricity or gas supplies come into the building and are seldom easily accessible for consumers. The majority of consumers have difficulties in locating their meters, or do not easily understand the information displayed on the existing meters. The introduction of smart metering in combination with feedback devices can change this to the benefit of the customers. The most common benefits in short are:

- The end of estimated bills. The benefit of more frequent bills based on real consumption and without waiting for a meter reader, will certainly appeal to most consumers' imagination. It will also tackle some of the serious debts which arise when estimated bills grossly underestimate actual consumption. On the other hand, accurate bills mean that energy costs can also rise strongly in certain periods of the year, which could be hard to bear for the most disadvantaged in society.

- The provision of historical data on bills to show how energy consumption compares with the same billing period of the previous year.

- The possibility to become more aware of household energy consumption and the ability to better manage energy consumption, resulting in savings on energy bills.

- The ability to switch the supply contract between debit and credit without requiring manual intervention or the installation of prepayment meters.

- The ability to switch more easily between energy suppliers.

- The ability to adapt energy consumption patterns to take advantage of time of use tariffs and hence lower costs.

- The ability to install micro generation measures without new metering arrangements.

- The possibility for prepaid or post paid schemes and easier credit, either by phone or internet for pay as you go meters.

In the presentation of these advantages, the eventual disadvantages should not be forgotten:

- Smart metering can lead to more automation, privacy concerns and can be more vulnerable to misuse of systems or data by criminals, vandals and hackers. These concerns should be solved by good security and appropriate regulation of the access to, and use of, the data.

- Careless introduction of smart metering and related possibilities (e.g. differential tariffs) may lead to higher costs for some consumers or another form of decreased final customer satisfaction.

But all in all, it seems that these disadvantages can be overcome and will not outweigh the advantages. Careful piloting of both meters and feedback is essential to minimise the disadvantages.

3.2. Types of feedback for consumers

International feedback experience in demand response pilots covers a wide range of practices. These practices can best be understood by looking in terms of their contribution to the technique of information dissemination and data presentation as part of a learning process. People take in information concerning their energy use, they gain understanding by interpreting what has happened and finally, they act/change their behaviour in some way.

Demand response is a generic term for energy delivery programs to residential and commercial customers that combine supply with additional communication efforts in order to encourage (or eventually enforce) reducing or shifting energy consumption for the benefits of security of supply and climate conservation. The communication can be based on pricing (incentive pricing and tariff schemes), limitation (load control/ pre payment) or on consumption feedback information. The general communication objective of demand response is to create pro-active customer participation (peak shifting or energy savings) through greater awareness and an increased sense of responsibility.

Effective demand response schemes often include technical equipment such as smart meters and communication applications to add feedback functionalities to the smart meters. The level of advanced feedback functionalities will enable the full potential of demand response.

This paragraph divides feedback into basic types, based on a mix of various degrees of:
- ease, immediate and continuous information dissemination;
- type, quality and quantity of data presentation;
- interaction and control by the energy user.

The basic types of feedback that can be distinguished are:

1. Indirect feedback that has been processed before reaching the end-customer and mediated through another channel;
2. Direct feedback in real time, either through an individual associated in-home display (whole house or appliance specific) or as part of a pre payment program or time related pricing structure.

These basic types of feedback are described below.

Indirect feedback

Important characteristics for indirect feedback are that end-customers:

- have no direct access to actual consumption data;
- respond to previous consumption behaviour (which may have a lower information value);
- need to switch to another medium channel (e.g. bill, website etc);
- need a level of commitment regarding regular use and interaction;
- have to rely on processed information.

Examples of indirect feedback are frequent (e.g. day-to-day) feedback through an interactive webpage on internet, PC, e-mail, SMS or frequent periodic informative billing. These types of feedback are based on smart meter readings with a combination of:

- historical feedback;
- comparative feedback;
- normative feedback;
- disaggregated feedback (e.g. the heating load at different times of year);
- detailed annual or two-monthly energy reports.

Research findings indicate that savings from indirect feedback range from 0% to 10%, but can vary according to context and the quality of information given. There are also indications that indirect feedback is more suitable than direct feedback for demonstrating effects on consumption of changes in space heating, household composition and the impact of investments in efficiency measures or high-consuming appliances. In other words, indirect feedback will show up longer term effects best, such as investment in insulation, use of new appliances, replacement of heating systems and appliances, home extensions, new members of the household.

Better billing can - when combined with an in-house display - contribute to final customer awareness of energy and environment and help them to make reduction decisions. Of course information alone will not deliver energy savings. However once consumers are aware of their use, particularly in times of increasing energy costs, it is reasonable to believe that they are much more likely to reduce usage.

Direct feedback and individual in-home displays

Ideally, every household should continuously and instantaneously be able to see what is happening to consumption and directly respond to it without having to switch on an optional feedback service. The main characteristic for direct feedback is that final customers have an easily-accessible display monitor, associated with the smart meter. The role of the meter is to provide a clearly-understood point of reference for improved feedback in combination with a separate, free-standing or easily accessible and easy to understand display monitor in the building. The consumption information displayed can either be in kWh, in currency or CO_2 and be presented at a total level or at a more disaggregated level (depending on sub-meters or on signal recognition capability).

Taking data directly from the meter also means that the information can be real time, greatly increasing its value and effectiveness. Recent developments in domestic communications provide paths for the data and destinations. For instance, the data can be transmitted via Wi-Fi, Bluetooth, PLC, and Ethernet (see Chapter 4 “Smart metering systems - technical options”) to a standalone display, the TV or a home PC. All of these destinations allow the data to be brought in somewhere convenient for the final customer. Data visualisation through a standalone direct display is in this respect most interesting. Both TV and Internet/PC require final customers to make an extra effort to locate the information (and therefore are considered to be indirect feedback).

A well known example of direct feedback is an associated direct display on a monitor separate from the meter. Householders can look at the displays for instantaneous information and in some cases they can also set an alarm to go off when the load rises above a level chosen by them. A potentially effective way to increase the final customer’s awareness is to provide them with special in-house displays of readable, easy to comprehend energy use information, in a display design chosen by them. Once the consumers can see the changes in their energy use instantaneously on a display design chosen by them, they are much more likely to act to reduce that consumption, particularly in the present higher fuel pricing environment.

According to Parker, Hoak, Meir and Brown [Parker 2006], there is a parallel with hybrid automobiles (e.g. the Toyota Prius). Here accumulating evidence suggests that feedback from dashboard-mounted displays allows drivers to improve their mileage as they learn from experience. The important reason for this is that drivers suddenly have an immediate feedback about how various aspects of their driving habits shape mileage.

Research literature indicates that savings from direct energy feedback devices range from 5% to 15%. Savings are typically of the order of 10% for relatively simple displays [Darby 2006]. Over half of those interviewed during trials said that they would like to have such a display permanently. There are also indications customers with a high energy use may respond more to direct feedback than customers with a low energy use, because direct displays best show up the significance of moment-to-moment behaviour.

Real-time feedback can possibly also tell the final customer about the relative importance of different end-uses. For instance, an instantaneous, easily accessible display may show the surge in consumption when the kettle is switched on, or the relative significance of a radio, vacuum-cleaner or toaster. Presumably for this to be effective, the display must react within a given time – less than the duration of the activity. At present, fully disaggregated feedback using signal recognition of different appliances is relatively expensive and complicated to supply, though this may change within the next few years. Customers may need guidance on the relative importance of large short duration loads, compared to small long duration loads.

Direct feedback and prepaid systems

Older prepay meters tend to be 'semi-smart', because they lack a two way communication module within the meter. Other relevant characteristics of traditional prepayment are the focus on budget management of costs and the transfer of information such as tariff-changes and meter reading data to and from the key code at the payment point or shop.

Modern prepaid systems however have the potential to be much more than just a traditional option to low-income final customers in general. Research literature indicates that savings to date for all keypad final customers are estimated to range broadly from 3% to approx. 15%. An example is the situation in Northern Ireland where prepayment has been offered to all final customers; 27% have taken the option, only 45% of whom are classed as low income [Oxford 2008].

Direct feedback and time related pricing (different tariffs)

Time related pricing is important in those parts of the world with:

- summer and winter peaks in demand allied with supply constraints: California, Ontario, the north-eastern states of the USA, Nordic countries, parts of Australia and southern Europe;
- fluctuating market prices due to high penetration of intermittent generation (such as wind power in Denmark) or high penetration of invariable generation (such as nuclear power in France).

Regarding electricity tariff structures, it is relevant to distinguish between pricing of electricity (as a commodity) and transmission and distribution of electricity (as a service). In deregulated electricity markets, formation of the price for these two things is different:

- The commodity prices is based on market transactions and should ideally correspond to the electricity generation costs;
- The distribution tariff is regulated as a natural monopoly and reflects the allowed costs for investments in and maintenance and operation of the transmission and distribution infrastructure.

This is relevant, because in some countries such as the Nordic countries, final customers receive separate bills for these.

In general, three broad types of time related pricing methods can be distinguished:

1. Time-of-use / time-of-day tariffs reflect daily and seasonal variations in electricity costs. These are fixed in advance based on estimated costs. These tariffs reflect expected costs during peak, shoulder and off-peak periods of the day. Customers are informed of the different time periods and prices on their bills and on their meter display. Time of use tariffs are widely used in Finland for instance.

2. Actual cost tariffs (real time pricing/ spot pricing) require final customers to pay, in each (half) hour period, the actual cost of electricity. The price is usually known shortly before the time of use.

Customers are alerted to these prices through the meter display. This form of pricing is in use in Norway and is planned for introduction in California.

3. Critical-peak pricing is the application of different prices for specific hours of the year, when the system is stressed or hourly energy market prices are high. In this case, final customers pay a time of day price most of the time and a high or critical peak price at times when it is important to reduce demand. This type of pricing is used in France (called the *Tempo* tariff) and final customers see a red light on their meter a day before the critical peak period begins.

The main advantage of time-of-use pricing is that final customers know the price well in advance of consuming electricity. However, this may also be the main disadvantage, when price variations in the market do not follow regular patterns. In order to provide final customers with predictable prices, such tariffs are unlikely to reflect the actual cost of producing electricity at any point in time (as the prices are set in advance and based on forecasts of costs). Real time pricing trades predictability for price accuracy, while critical peak pricing falls somewhere in between real time and time-of-use pricing in terms of predictability and accuracy.

The main purpose of time sensitive pricing is not end use energy savings. They may even increase energy end use. The point is that the total energy consumption in the whole system is, in most cases, reduced by responding to market prices and system requests. This because less efficient generating plants, which are normally used to meet peak demand, are required less often. That is a goal of any reasonable energy saving policy. The primary energy saving from demand response however depends on what peak generation plant is no longer required.

In Scandinavian countries there is much electrical heating and therefore a lot of potential for real time pricing. In countries with summer peak, as in southern Europe, air conditioning and cooling loads also have much potential for real time pricing. In other parts of Europe, there seems to be less scope for load-shifting among domestic consumers. Moreover, most households have gas heating, while almost all the rest use off-peak electricity, oil or solid fuel for their heating. In short, opportunities for reducing peak usage seem to be limited. Nevertheless, time-of-use or real-time pricing may become more important as part of more sophisticated demand response policies and as more air-conditioning or distributed generation come on stream.

Load management in non-liberalised markets

The term Load Management is known in non liberalised markets under other names such as direct load control, demand side management, peak load control, etc. Reducing maximum capacity at critical time periods (peak load shifting/ trimming) can be exercised either indirectly, as described above, when the customer makes choices in line with time-sensitive pricing options offered by the utility (demand response), or through utility-controlled load management (direct load control). Direct load control only involves feedback in an automated sense. For example, changes in electricity demand can trigger the switching off or on of appliances, or, when household renewables are available, their output can be matched to the use of appliances such as washing machines.

The extent to which load management leads to carbon emission reductions depends on the way the electricity system is implemented and in practice different results are obtained. There is no general conclusion. But reduced demand or the reduction in use of high carbon intensity generation plant at peak periods can lower emissions. King and Delurey discuss the relationship between demand response and demand reduction [King 2005]. The benefits in terms of security of supply are clearer cut. Direct load management can have other effects if combined with the use of smart appliances, building services and household renewables. The ability of a washing machine, for example, to only operate when there is a low carbon electricity supply available can increase the carbon abatement possibilities significantly. More about this subject can be found in Chapter 7. Smart metering services for demand response.

3.3. Lessons learned from experiments and field trials

In the last couple of years, there has been growing interest in the potential benefits of introducing smart metering and how this should be done. It has become a ‘hot’ topic in countries such as UK, USA, Canada, Netherlands, Italy, Australia and Scandinavia. Despite these recent developments, there is still relatively limited quantitative evidence from recent smart metering projects designed to promote energy savings in households. Researching the effectiveness of feedback on gas and electricity consumption does not have a long and intensive (scientific) tradition. Most evidence so far is based on small-scale trials and only very few have been longitudinal enough to judge whether the response is likely to last or can be built upon. Further, complicating factors are the low level of interest of most consumers in their energy usage, the difficulty of measuring feedback savings and the minimum persistence of effects for at least three months. Chapter 10 “Determining energy efficiency gains using field trials” expands on this topic.

Another complicating factor to be expected from experiences from field trials is the difficulty of comparing these studies. All contain a different mix of elements such as sample size, housing type, additional interventions, and financial influences, household composition, feedback frequency and duration. Further, recorded feedback savings can dramatically differ according to the technology under consideration, the quality of feedback information and the way in which studies are conducted, the institutional and cultural background (lifestyles) and of course climatic conditions against which the study takes place..

The best feedback technique is likely to evolve over time as various approaches are tried and evaluated. Home ICT is evolving very fast and in a landscape where all appliances and multimedia applications will be linked together, innovative techniques like pop up messaging on the TV set when it is put on could be more effective than a specialized screen displaying the same messages all the time.

Nevertheless, this Guide includes lessons from what is known so far about the effectiveness of feedback to householders regarding energy consumption behaviour. As stated before, it is expected that within a relatively short period of time a lot of experiments that are currently underway will deliver new insights and other experiments will be started. So this section is about basic understanding of the factors that influence the impact of smart metering and feedback on consumer demand.

Top 5 key findings of feedback

Energy feedback can take many forms and several studies have analysed the effect of feedback on domestic energy behaviours [i.e. Abrahamse 2005 and Darby 2006]. Feedback *methods* include giving final customers instantaneous, historic or comparative feedback, prepayment / pay-as-you-go, or any of these in combination with other types of information. *Technologies* include advanced billing, displays, internet etc. Based on a broad sample of experiments and international literature reviews, the Top 5 interesting findings regarding the use of methods and techniques of feedback are:

1. Time between behaviour and -accuracy of- feedback on resulting energy use and cost is crucial:
2. Direct feedback seems to be more effective than indirect feedback (up to 10% for indirect feedback, up to 15% for direct feedback and up to 20% in pre payment programs);
3. Feedback seems to be more effective when accompanied with goal setting;
4. Historic feedback seems to be more effective than comparative or normative feedback;
5. There is more preference for information feedback through an enhanced direct display than through a website.

The last finding is particularly interesting for countries with a high level of internet penetration and on line tasking such as in the USA. According to a National Residential Online Panel In-home Display Survey, conducted by Energy Insights in October 2007 [Borstein and Blackmore 2007], more than 60% of the 270 respondents preferred to have some sort of direct display for energy information and communication. Only 3% of the respondents preferred an internet website.

The last finding also seems to account for most European countries, according to a pan European market research in 2007 on the role of information and technology and consumer preferences regarding the use of feedback technologies in facilitating energy saving behaviour (see Table 3.1 below).

Table 3.1 Preferred communication technology for receiving smart meter feedback information (More options possible, boldface indicates highest score)

Country involved in market research	Information on screen / direct display	More detailed bills	Personalized web page(s)	Telephone services
Finland	**68%**	46%	34%	10%
Norway	**54%**	29%	32%	10%
Sweden	**49%**	28%	39%	5%
Denmark	**58%**	29%	41%	10%
Netherlands	**39%**	25%	23%	10%
France	**57%**	53%	28%	9%
Germany	61%	**66%**	32%	5%
Great Britain	59%	**61%**	30%	20%
Spain	50%	**73%**	29%	23%
Portugal	22%	**32%**	18%	5%
Average	55%	**57%**	30%	11%

Source: Logica CMG, based on TNS/ Future foundation research, 2007.

Although the results vary greatly depending on the country surveyed, looking at Europe as a whole, there is a clear indication that the most preferred method of receiving smart meter information is not through personalized web pages, but either through a screen/ direct display showing up-to-date energy usage information or through more detailed billing.

Just as in USA, the low preference for a personalized webpage is surprisingly clearly visible in the European countries with the highest levels of internet penetration, such as the Scandinavian countries. Most consumers here are experienced users of the internet and often more inclined to carry out a wider range of tasks on the internet, including bill payment. Research carried out by Nvision in 2007 [Logica CMG 2007] found that 92% of Norwegians, 79% of Swedes and 68% of Danes had paid a regular bill online in the past six months, compared with a European average of 23%.

More detailed billing will probably become popular in Spain, Portugal and Germany, but finds less favour in the Scandinavian countries, Denmark and The Netherlands. Consumers in these countries prefer to receive information as and when they want it, either on a personalized web page or on a display.

Telephone services such as call centres only find favour in Spain and Great Britain as a method of delivering information. In Great Britain consumers are familiar with these centres as a method of obtaining information although something of a national love/hate relationship exists (with sentiment skewed toward the latter). It is therefore reasonable to assume that higher than average preference for call centres comes from familiarity rather than affection.

The broad European preference for direct displays and more detailed billing instead of personalized web pages is a rather surprising outcome. This indicates that consumers point at an important shortcoming of web based applications: there is a latent but strong desire of consumers to get information on energy consumption that is immediate, instantaneous and continuously visible. Consumers realize that energy is invisible to the user and that they have only a vague idea of how much they are using for different purposes and what difference they could make by changing their day-to-day behaviour or investing in efficiency measures. In order to manage their energy consumption better, consumers simply need to see what is happening to consumption, without having to switch on an optional feedback medium.

However, it must be stressed that –although the internet is unlikely to become an adequate communication substitute for a direct display- web services and on line billing can provide useful interactive feedback and can incorporate further analysis and advice on a more long term basis. This finds support in a recent market survey, in the UK [ONZO 2008]. This survey showed a close correlation between the preferred type of device on the one hand and the type of decisions consumers take on the other hand:

- Direct energy display for real time insight and rapid tactical decisions (seconds/ days);
- Web services to view longer term effects of their actions goals (weeks/ months);
- Bill/ personalised reports to view long term trends and advice on strategic decisions (month/ years).

3.4. Examination of energy and pricing display devices

It is generally expected that consumer interest in, and demand for, in-home energy displays will grow rapidly. Although the use of in-home energy display devices is still limited, they represent a ready technology to educate customers about their energy use and maximize participation rates for energy conservation and dynamic pricing programs. For this reason, energy and utility companies are increasingly interested in the potential of these devices to affect customers' energy use behaviour.

This chapter focuses on the latest developments in in-home displays by illustrating examples of the energy information technologies currently available on the market or soon to enter commercialization. The purpose of this information is to assist energy companies and technology vendors in getting up to speed rapidly and staying abreast of developments relative to in-home displays in the energy industry. While doing this, it is at the same time interesting to take note of two fundamental changes that take place in the development of in-home displays.

The first fundamental development is a shift from ‘non-communicating’ towards more ‘communicating displays’.
Most existing relatively simple in-home display are primarily designed to provide energy only information such as electricity usage and are not integrated with utility metering systems or home automation networks (HANs). This means that there is no communication with the utility and no possibility to handle dynamic pricing. The display data collection depends on techniques such as an optical sensor or a current-transformer (CT) at the electrical panel. A well known example of this type of display is The Energy Detective (TED), which is described below.

But now a new generation of devices is coming into commercialization that can communicate with smart meters to provide dynamic rate information, appliance control and other advanced features.

Within this new generation of communicating displays, another interesting development is occurring: a shift from utility based displays towards more customer based displays. Many of the new communicating energy displays that can be connected to some type of (smart) network can only work in conjunction with that specific metering system. The communicating energy displays are primarily designed to help the utility to control energy load and achieve better demand response during peak events. An example of this type of displays is the Ecometer, a display monitor that exclusively works with a Landis+Gyr meter with a communications chip.

But recently a growing number of energy displays can be qualified as customer centric. These displays can be installed individually, do not depend on a specific utility network and allow the customer to respond at the level of energy use they are comfortable with. An example of this type of displays is the ONZO a stylish, modern designed display monitor which is described below.

The Energy Detective (TED)

The Energy Detective (TED) by Energy, Inc. is an energy display that shows instantaneous kW and month-to-date kWh. It also projects what the use at end of month will be. It is somewhat programmable for complex rates such as time-of-use. TED communicates the data via power line to the display unit, which can be moved and plugged into any outlet. Data displayed include: instantaneous use (kW and $), use today (kWh and $), use month-to-date (kWh and $), projected monthly bill, peak demand (kW and $), voltage (current, highest and lowest today), and current electricity rate. It also has an alarm that can be programmed in various ways: if cost/hour or kW/hour exceed limit, if $ or kWh per day or month-to-date or monthly projection exceed limit, and for low or high voltage.

Figure 3-1 The Energy Detective (source: Energy Inc.)

The design is very simple and easy to read. TED displays instantaneous and month-to-date energy use and cost. It also has an audible alarm and red and yellow LEDs. TED stores 2 months worth of hourly readings. The user can download the data to a computer for further analysis. TED is very accurate and programmable. The user can input rate details, including flat fees, time-of-use or demand pricing, and taxes. Based on these data, TED can estimate the electric bill accurately. However, there will always be some discrepancy because the exact time of the utility read will vary. TED is a so-called clip-on device and requires electrician to install the current transformer. Data is communicated to display device through power line communication. The display itself can be plugged into any standard electrical outlet.

Ecometer (Landis+Gyr)

The Ecometer is a wired or wireless display monitor that exclusively works with a Landis+Gyr meter with a communications chip. The monitor communicates with the metering system and can display load profile data for electricity, gas and water. In the optimal configuration the meter and display unit are part of an integrated utility communications infrastructure network. The display gets the data directly from the meter and is programmed with all components of the utility tariff. Because the meter has two-way communication with the utility, it can accurately show energy cost for excessive usage, current Time-of use-pricing and usage based on cost information that matches the bill exactly.

An interesting extra is the visual colour coded indications running from red to green to indicate the level of consumption or current energy tariff down to customer level. It also shows historic and carbon data.

Figure 3-2 Ecometer (source: Landis+Gyr)

ONZO

The ONZO is a stylish, modern designed portable consumer unit from the UK that monitors energy consumption, sometimes referred to as the "dashboard for your home". ONZO's battery-free innovative energy display works with a smart meter in order to provide real-time feedback on energy use by interactive sharing information with a computer to allow comparing performance with others and analysis of energy usage down to the appliance level.

Figure 3- -1 ONZO energy display (source: ONZO)

The Onzo collects and logs electricity data directly from the meter in order to help consumers determine carbon emissions with advanced metering infrastructure devices (gadgets), such as a wireless PC dongle, individual appliance meters and clip-on sensors and a web interface where users can chart and track their energy use. Once the ONZO is hooked up to a computer, it will take the customer straight to a website with information for comparing one's home's carbon footprint over time — or with everyone else.

Energy company Scottish and Southern Energy (SSE) is behind the financing because they hope to find a marketing advantage by giving their customers the Onzo as a more powerful tool for power management.

3.5. Recommendations

When designing customer feedback for smart metering schemes, the following observations should be fully taken account of:

- Consumers need to be able to see instantaneously and continuously what is happening to their consumption, without having to switch on an optional in-home feedback device first;
- Direct feedback promises to be more effective than indirect feedback;
- Feedback promises to be more effective when accompanied with goal setting;
- Historic feedback promises to be more effective than comparative or normative feedback;
- Direct displays in combination with better billing promises to be a more preferred way of communication for consumers than feedback through an indirect (delayed) personalized web page
- Internet promises to provide useful additional feedback through incorporation of further analysis and advice on a longer term basis.

Regulators should ensure that there are no financial, commercial, legal or regulatory barriers to customers having access to real time data from utility meters measuring their supply.

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4. Smart metering systems - technical options

There are numerous technical options facing anyone looking to implement smart metering. This Application Guide cannot ignore this issue as it has a strong bearing on the success of any smart metering scheme. It would not be appropriate, though, for ESMA to promote any given technology over and above others, unless there is good evidence to recommend it. What is appropriate, however, is for this Guide to provide an overview of smart metering technology, especially where this impacts on how smart metering can better deliver energy efficiency improvements. Therefore, this chapter seeks to:

- Set out the broad technical options open to anyone implementing a smart metering scheme.
- Identify the key issues which should influence any choices made.
- Focus especially on the technical options and choices relating to final customer feedback.
- Maintain a neutral stance on the respective claims of competing technologies unless good evidence is available to support one over another and only where this relates to energy efficiency benefits.

Smart metering systems comprise a number of interconnected elements as shown in **Error! Reference source not found.**.

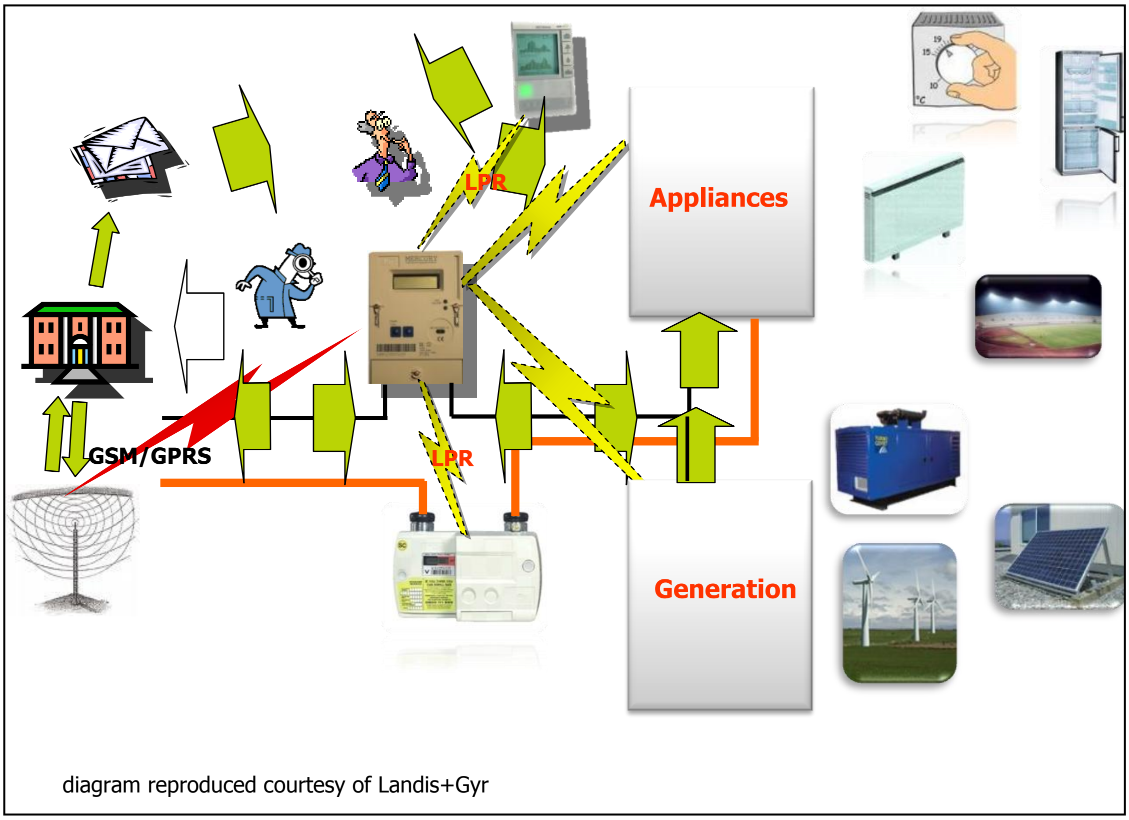

diagram reproduced courtesy of Landis+Gyr

Figure 4-1 Smart metering system

Technical options for these elements are described in detail below.

4.1. Meter design options

Measured quantities

All utility meters purchased for billing purposes in Europe must comply with the Measuring Instruments Directive [MID 2004]. This specifies the minimum requirements for fiscal meters, including their accuracies, divided into a number of different classes, appropriate for different market applications.

The MID also specifies the quantities that meters must measure:

- kWh of active energy for electricity;
- kWh for heat meters;
- m^3 or kg for gas.

Other quantities that can be measured and recorded are:

Electricity	Reactive energy
	Instantaneous power
	Power factor
	Voltage
	Current
	Maximum demand
	Export energy (active and reactive)
	Selected power quality characteristics
	Disaggregated consumption data (individual appliance loads)
Gas	Energy (if provided with a calorific value for the gas)
	Instantaneous flow (for ultrasonic and similar gas meters)
	Maximum demand
	Smoothed consumption data approximating to the steady heat output (where the boiler is modulated through a simple on/off control)
Heat/Cooling	Flow rate
	Temperatures (supply, return and difference)
	Maximum demand
	Instantaneous power
Water	Flow rate of cold water
	Flow rate of hot domestic water

All of these quantities can be used as inputs to a smart metering scheme if specified in the meter design.

For the purposes of energy usage feedback it is possible to provide further information based on these measured quantities:

Electricity	Inferred disaggregated consumption data (individual appliance loads) –

	requires access to high frequency data from meter Cost, instantaneous and cumulative Carbon, instantaneous and cumulative Prediction of the next bill
Gas	Smoothed consumption data approximating to the steady heat output (where a boiler is modulated through a simple on/off control) Cost, instantaneous and cumulative Carbon, instantaneous and cumulative Prediction of the next bill
Heat/Cooling	Cost, instantaneous and cumulative Carbon, instantaneous and cumulative Prediction of the next bill
Water	Leakage Cost, instantaneous and cumulative Carbon, instantaneous and cumulative Prediction of the next bill

Clearly, adding measured and calculated quantities will tend to increase meter costs, depending on the need for additional hardware. This is not always a simple calculation as, in some cases, additional functionality can be provided with small changes to the design whilst some additions require a step increase in meter memory, processing capacity, or communication bandwidth.

Time interval

Measured quantities can be recorded over different lengths of time. For conventional metering systems there are two options; interval metering, where the consumption is recorded over time periods from 5 minutes up to 60 minutes. Alternatively, a single consumption value can be taken over longer time periods, related to the frequency of the meter read visit. Non-interval readings can vary between monthly to annual, (with actual meter read frequency depending on access to the meter).

Electronic meters can, in fact, provide much higher data rates (down to intervals of a second) but such short time intervals are not used for billing because this provides no benefit to the billing process and greatly increases the cost and quantity of data transmitted. With smart metering it is an option to stream short interval data directly to a local device without feeding it into the billing data network.

In general, for final customer feedback, shorter periods are more informative [Elburg 2007], although there is no consensus at present on the precise data rate for positive final customer response. The data rate needed depends on two things; the time constants of the load dynamics being viewed and the value of energy that can be used in one interval. Short time intervals of a few seconds duration represent negligible amounts of money (1 kWs = 1 kWh/3600) but where feedback is being used to identify the loads of specific appliances, the refresh rate should be fast enough to link the change seen on the display with the operation of the appliance; from which it follows that intervals should be in the order of seconds. For example, the Electrisave device [2save energy] has a refresh rate of either 1 second or 6 seconds. Where meters or displays rely on battery power, there will be a trade off between higher frequency and lower power consumption. This may have a major impact on the choice of refresh interval for these devices. Some loads may also be harder to interpret when viewed over short time periods; an example would be gas boilers with simple on/off modulation where the load is either full on or zero.

Disaggregated Data

A number of developers, including Sentec and Oxford University, are producing devices that can calculate the energy usage of individual loads based on the total consumption data recorded at the meter. To make these calculations, the meter data must be analysed at high frequency as the different loads are distinguished by their effect on the power signal. It can be implied from this that the disaggregated data must be sourced from the meter or a separate sampling processor. A normal meter will not provide a sufficient data resolution to carry out this analysis remotely; such devices must be built into the meter.

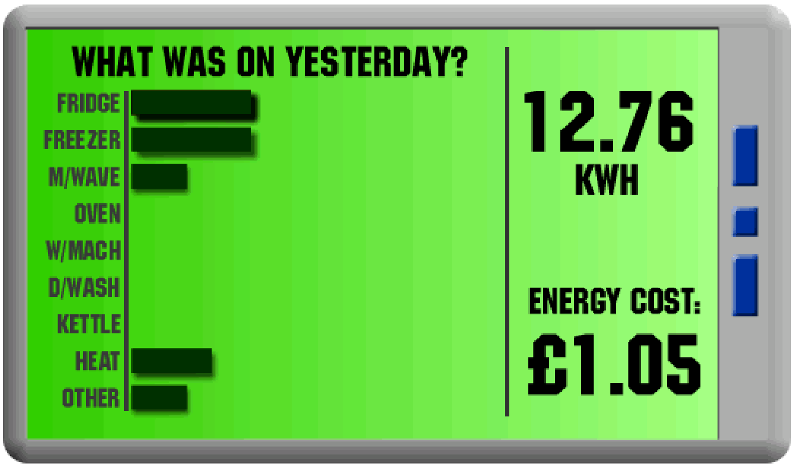

Figure 4-2 Sentec Coracle

Switch/Valve

Meters can be fitted with a switch or valve to interrupt the supply. There are a number of reasons for fitting such a switch. Firstly a switch can be used to limit the maximum demand of a given final customer - remote load limiting. This can be useful where there is limited supply capacity or where peak loads are growing faster than the network can be reinforced. This is a growing issue where residential final customers are purchasing air conditioning units. Such schemes do not depend on smart metering as they are in widespread use already, but smart metering can be used to manage such schemes and perhaps enable variable loads to be imposed.

Another reason is to enable prepayment options. The combination of a switch or valve in the meter with an appropriate payment method defines a prepayment meter. The UK is the European country with the greatest use of prepayment (3.5 million electricity meters and 2.5 million gas meters) but it is not the only country where they are used and smart metering systems would ideally accommodate prepayment. Incorporation of prepayment functionality into smart metering would also overcome a major objection to prepayment, which is that the higher costs of the meters and payment process results in prepayment customers facing higher tariffs. If all final customers had meters that could be remotely switched between prepayment and credit mode, then all final customers would have the same meter costs. The main addition to a meter (in cost terms) to provide prepayment functionality is a power switch. It can be argued that fitting a switch to every meter to do this when prepayment represents only a small proportion of the meter is an unnecessary expense. However, the switch can also be used to allow the supply to any site to be turned off, a function that may go towards justifying the cost of the switch.

If prepayment is enabled in a smart metering system, then the system will have to be able to handle payments. This can be done by either using a process local to the meter or by carrying out the processing remotely on the utility system. Again there are possibilities for reducing the current cost of prepayment systems by utilising the greater functionality of the smart meter system. A prepayment system will have its own detailed technical requirement, but these have not been dealt with in this chapter as it only relates to a small market sector across Europe.

Finally, a switch or valve fitted to the meter can be used for remote meter management and allow the utility to disable supplies to properties that have ended their supply contracts without entering into a new contract with an alternative retailer (energy retailers). Such properties with conventional meters can be difficult to access. The use of remotely operated switches raises issues around how they can be safely re-enabled. It is normal practice with prepayment meters to provide a local switch on the meter, as it is not possible remotely to check the safety of the installation before re-enabling the supply. There is also concern that the meter switch and valve should not be used for long term isolation of supply, as the switch/valve provided is not intended for isolation. It is very important that those specifying smart meters should be clear about the requirements for any switches; are they required to interrupt the supply or isolate it. These are different functions.

Multiple and dynamic tariffs

Currently residential tariffs are normally limited to one or two tariff rates. This is a result of the difficulty of accurately collecting multiple register data from manual reads. Smart meters with automated data collection can overcome this difficulty and allow multi-rate tariffs to be offered, where the meter records the consumption to different registers at different times of day. Up to eight registers are being considered in the UK smart metering specification [SMOF]. With the ability to communicate with the meter it is also possible to remotely reset the tariff rates, say for example, if there was a high system demand foreseen. In principle, the tariffs could even be dynamic, varying daily, or even more frequently, to reflect higher or lower availability of renewable energy resources such as wind or wave power. This topic is dealt with in much greater depth in Chapter 7” Smart metering services for demand response”. For the purposes of this Chapter it is sufficient to note that the number of registers must be considered during the design of the smart metering system as well as the ability to securely change tariffs for each register and to ensure that the registers are correctly read.

Meter configuration options

Smart metering depends on frequent access to the data in the meter, with the data being transferred to a wide area network or to other devices inside the final customer’s property. This data can be acquired in a number of ways and the various options are set out in Appendix 1. Basically, the data can be provided by fully functional smart meters that also provide all the other features of smart metering (which can be configured in a number of different ways), by add-on devices that gather data from the meters in various ways and, finally, by devices that are entirely separate from the meter.

The main open issue at present is whether final customers will respond positively to feedback data alone or whether they also need the additional smart meter functionality, such as demand management and communication with the energy retailer, before they make a reduction in their consumption.

4.2. Wide area data communications

For smart metering, it is necessary to be able to communicate remotely with the meter. This is enabled by a Wide Area Network (WAN). There are a plethora of options for WAN communications for utility meters and the choice of WAN is complicated by the fact that the options are interdependent, so that there are not a number of independent options, but rather a complex matrix of options. WAN area communication equipment tends to be the largest individual source of costs, limitations and risks over the lifetime of a properly functioning smart metering system. Thus a detailed comparison of communication alternatives is important.

Major design considerations for WANs

All Wide Area Networks must address the following requirements:

Universality	Smart metering systems must be able to meet the needs of the vast majority of installations as costs escalate if there are numerous different implantations. This is not to say that there cannot be different WANs located in different geographical areas; for instance different regions could have their own variety of PLC or wireless mesh network. It must be remembered that when remote meter reading eliminates routine house calls, any remaining manual meter read visits will become more expensive as the cost of any given trip will no longer be shared between so many visits. Thus it is essential that there are very few properties that cannot be included in the smart metering scheme. A common approach also implies that there will be technical limitations to the number of different energy efficiency measures that can be supported with a common meter specification. It should also be borne in mind that in many countries meter installation practice will have varied widely over many years. An important activity prior to any smart meter implementation will be to survey the meter stock around the target area and assess the variations in meter installations. Meter manufacturers should be advised of specific instances where a meter design variation might be needed to overcome a specific challenge. This will also allow the project managers to understand the time and cost required to install the meters and the expected number of sites that will be excluded from the system.
Reliability,	A major advantage of smart metering is the avoidance of visits to meters.

availability and transfer time of WAN communication	Any increase in unreliability will have a serious impact on this benefit if it makes visits necessary. This must be considered in the cost benefit analysis and this in itself is difficult, as the long term reliability of new hardware and systems is currently unproven. Most modern meters store metered values for several weeks or months (depending on how much memory is specified) thus reducing the risk of losing billing measurements due to WAN reliability problems. Some other services (such as dynamic tariffs) require much higher availability and faster transfer times than settlement and billing. Meeting their availability and long maximum transfer times can be difficult or expensive with some popular WAN solutions used for remote meter reading.
Security	Smart meter systems are vulnerable to hacking attempts as they are widely accessible for extended periods and control large financial values. Any WAN must be designed to detect and prevent unauthorised access attempts. As the computing power of home computers can be expected to rise considerably over the lifetime of the smart metering system, the meters should be able to remotely accept improved security algorithms during their service lives. It should be anticipated that this may require the provision of spare memory and processor capacity. At the same time the security must be provided in an efficient way as static meters do not have extensive memory or processing power, even more so for relatively dumb devices communicating with the meter.
Support	Whatever system is installed there will be a need to maintain it. There will be considerable pressure from the meter operators to avoid a proliferation of protocols and hardware options. This will be a financial and practical consideration related to the number of components that must be kept in stock and carried by technicians in the field. It is also possible that a change in the functionality of meters will result in different calls from final customers; perhaps needing support in the energy saving functions of the meters. Appropriate training for call centre staff and technicians would be needed to deal with these questions.
Data accuracy and consistency	Utilities have a legal duty to provide accurate billing data to their final customers. Non-fiscal data that is only intended for energy usage advice does not have to be accurate from a legal view point but it is likely that, if conflicting data is provided by the utility via displays and bills, then the final customer may be confused. This may cause a lack of trust in the data or calls by the final customer to the utility call centre. Hence, it is important that final customers receive consistent data, even when it is provided from different sources or via different routes. One challenge for designers of display devices is how to represent the instantaneous cost of energy when the contract is based on multiple rates, thus the final cost/kWh cannot be

	fixed until the end of the billing period.
Bandwidth	A fundamental question for any communications network is how much data is required to be transmitted in each direction. For simple monthly billing of final customers data rates would be typically low in both directions. For example, a monthly upload of 4 registers should not require more than 1kB of data per month. All current communications networks can meet such data rates. This should be compared with the requirements of broadband internet communications streaming multimedia, where the requirement is for > 1 Mbps. When designing the smart metering system it will also be important to avoid future bottlenecks by allowing sufficient headroom or upgradability in the data bandwidth to cope with growing data communications volumes. This would be especially the case if, in the future, energy retailers developed new offerings for final customers that involved more frequent or longer messages.
Speed of response	If data is simply required for billing then there is no need for rapid response, so long as the data is received within the billing window. However, where the smart metering system is to be used for demand response, there could be a need for a rapid response in order to deal with an imminent peak demand. In such cases, how the meters are addressed is significant, as this can be done on a one-to-one basis or on a group basis. If a large number of meters are to be sent the same message, a slower communications protocol with multicasting that addresses the meters as one block can be more effective than a faster network that requires all the meters to be addressed individually. A minimum speed of response is also required by low priority alarms that are needed by some possible services based on smart meters.
Public/Private communications networks	The WAN design must identify a path for the data from the home to the data centres. There are two fundamental options; a private network, such as Power Line Carrier (PLC) or Wireless Mesh where the meters are connected to a communications network installed by the meter operator or other agent. Alternatively they can use a public communications network, such as GSM mobile phone network. The economics of each choice are quite different; there is a relatively high investment for the private network but operating costs are lower. For the public network capital costs are lower as these are funded by the service provider. These costs though, are recovered by the network operator in their usage charges, either through a flat annual fee or on a message length basis. For private networks it is normal to connect a number of meters to a local data concentrator that provides access to the WAN. The capital costs are affected by the number of meters connected to each data concentrator, as the concentrator represents a fixed cost. Ratios as high as 800 meters to a

single concentrator can be achieved in city centres, falling to below 50 in rural areas. This means that the economics of private networks are better where there are high densities of meters, such as city centres, whereas, in rural areas, public networks can become more attractive. In locations where local ownership of meters is mixed, such as the UK, the difficulty of agreeing a common approach amongst energy retailers can act as a barrier to private networks unless the different parties can devise a way to combine their meter populations.

An issue for utilities seeking to promote final customer communication will be the relative cost performance of the two choices as communications increase. For the public network, the network operator will provide the additional capacity but the costs of call charges can be expected to rise. For private networks the reinforcement of the communications network will have to be paid for by the network owner.

Interoperability

It is attractive to meter owners to be able to buy meters from different vendors in the knowledge that they can work on the same WAN and LAN networks. Also, where energy retailers are competing for final customers, it is important for them that, if they win or lose a final customer to a rival energy retailer, the smart meter fitted at the property can be adopted by the new energy retailer and connected seamlessly with the new energy retailer’s billing systems. This will avoid costly visits to replace meters when final customers switch. This introduces the topic of interoperability. This is more an issue of standards than technology as meter vendors can offer meters manufactured to standards or to their own protocols. But the standards must exist if manufacturers are to work to them. There is also a major question on which level interoperability should prevail. Meters can be made identical, thus ensuring interoperability at every level but also limiting options for innovation. Alternatively, the communications software can allow the connection of different meters and provide interoperability at a higher application level. These issues are dealt with in Chapter 12 “Smart metering systems – standardisation”.

Multi-utility

Much of the focus of smart metering is on electricity metering. This is largely because electronic electricity meters are now widespread and because all electricity meters have a convenient power supply provided to them, unlike gas and water meters. However, smart gas, heat and water meters are available and the benefits of smart metering can be assumed to apply equally to all of the utilities. Implementation of non-electricity smart metering can be done in parallel with electricity meters using their own WAN networks or accessing the same networks as the electricity meters. Their functionality is greatly restricted by the lack of a power supply and an alternative approach is to use the electricity meter as a local hub and use low power radio communication to link the other utility meters to the electricity meter and hence to the WAN, LAN, utility and house applications. Multi utilities are dealt with in Chapter “Smart metering systems – multi-utility issues”. From a technical aspect the main issues relating to multi utility smart metering relate to the access to the WAN and LAN networks (dealt with below) and the extension of the systems software to allow other utility data entities (such as gas volume) and for them to be transferred to an appropriate agent; i.e. if energy retailers provide different utilities to a single final customer, the billing data for each utility must only be received by the appropriate energy retailer.

Wide area communications network options

The detailed design of a smart metering communications system needs to consider a number of key choices, notably the topology of the network and the communications path to the central servers. Many of these choices do not directly affect the final customer and so are not described in detail in the main text. However, to provide a full understanding of these topics amongst readers who are not familiar with smart metering then Appendix 1contains a full description of the various options for communications networks.

4.3. Software systems and data stores

Large scale implementations of smart metering will produce vast amounts of data, especially if utilities shift from quarterly or monthly meter reading to interval reading. A UK implementation of electricity smart metering with 30 minute resolution would produce annually 438,000,000,000 register readings. The success of this will depend crucially on the software systems that are used to collect and process the data, store the data and make it available to the appropriate users. Some software vendors would claim that smart metering is more about a total revision of the enterprise software than about remote meter reading. One issue that arises from this is that, if the data collection software is to be made interoperable with regard to data input from the meter, then the enterprise software must also be interoperable for data receipt. Work has been started on this with examples such as the Smart Energy Alliance with membership including Capgemini, Cisco, GE Energy, Intel, HP and Oracle [SEA] and the SAP AMI Lighthouse grouping including SAP and seven major utilities [SAP AMI Lighthouse]. Both of these groups are working to integrate AMI and enterprise software.

Another key issue is how to store the meter data and to make it available to approved users. For a vertically integrated and monopoly utility then this is less of an issue, although even here the customers and their representatives may have concerns over how the data is used. However, for metering in a competitive market, providing data to the correct parties is a challenge. For instance, if competing utilities are using the same system to collect multi utility data then it will be crucial that there is no leakage of data between the energy retailers.

One solution to this challenge is that adopted in Ontario where a data warehouse has been set up in a partnership between e-meter and IBM. Once established, this data store will be transferred to an agency that will be responsible for giving appropriate access to the data to current energy retailers, energy retailers taking over a customer contract and the DSO. Additionally, anonymised data can be made available to energy agencies so that overall energy trends can be analysed. Control of access to the data and its use will be a significant issue with customers and can be dealt with, as in this case, through the design and regulation of the system.

4.4. Customer feedback and local area communications

Customer feedback route options

If smart metering is to increase energy efficiency then it is assumed that there will be a need to feedback meaningful consumption data to the final customer. This can be achieved in a number of ways:

Via the bill or presented on the energy retailer web site - this approach largely depends on current systems and processes and is not covered further in this chapter.

Fed back to the final customer after it has been recovered to the central data servers – this can be done, for example, via SMS text message or the internet. Again, this is based on current technologies and is not covered further here.

Data can be streamed from the meters to local displays or devices – this is a relatively new approach and will require the implementation of new technologies (albeit, possibly already in use in other applications) and is considered further in this Chapter. The meter can be, and often is at present, used as the display but it is generally agreed that in many cases the meter location is poorly suited to this purpose.

There is some evidence suggesting that real time feedback is more effective at restraining final customer consumption [Van Elburg 2007]. This suggests the need for a LAN (Local Area Network) to support this feedback where the meter location is not suitable for final customer feedback. This LAN can provide a number of other functions as well as streaming data to a display; it can:

- Link other utility meters thus providing access to the WAN for these meters
- Provide a link to smart home devices (further discussed in Chapter “Smart metering services in smart homes”)
- Provide a link to generation meters for on-site embedded generators

There are a number of technical options for transferring data around a property. These include wireless systems (such as Z-Wave or ZigBee) wired (such as twisted pair cables), or PLC, using the mains cabling of the property. These are discussed in more detail in Appendix 1. The remainder of this Chapter examines the key issues for the LAN and effective final customer feedback.

LAN and final customer feedback design considerations

Whatever local area network is used, it must end up providing the final customer with a view of their energy usage data. How this should be done to best effect is very much open to debate at present and a large number of groups are working to develop suitable displays.

It is important that the feedback is available not only to final customer displays but for energy automation of buildings, control of embedded generators and controllable loads, smart home systems, pc's for energy analysis etc. It should be left open for competition and the final customer's preference as to which systems they use the feedback information with. Thus a standard open (but secure) communication interface from the meter to HAN is necessary for giving the feedback information. But only the possible tools for using, analysing and displaying the data to smart metering should be provided, not the whole application. This supports the views stated in [NERA 2008A].

Security	Access to final customer profile data can be useful for criminals in identifying when final customers are away from home or asleep and HANs must be secure and private. Access to the meter data must only be provided for approved agents or devices. Security protocols are now being made available, an example of this is the Certicom device authentication service that has been released for the ZigBee smart energy profile [Certicom, 2008].
Multi-utility and smart homes	LANs should be designed to allow access to other utility meters including gas, water and on-site generation meters, where appropriate. This link should provide an access point to the WAN for onward communications to energy retailers and other agents. The link should also allow data from other meters to flow to local displays, applications and smart homes communications networks.
Demand response and embedded generation	The network can be used for connecting other utility meters, linking to embedded generators, controllable loads and energy automation. Appropriate data entities should be provided to support these functions and routes provided to the appropriate devices. Displays should recognise on site generation and provide appropriate feedback such as total generator output, instantaneous generation.
Data transfer rate	For data feedback that is first communicated to the energy retailer and then back to the final customer, the quantity of data will have a direct impact on the cost of operating the system. It follows that the least data compatible with achieving the desired response from the final customer should be transmitted.
Installation cost	If the display is to be installed at the cost of the energy retailer, the installation cost cannot be high, as might be the case with extensive twisted pair cabling. Use of wireless communications can avoid cabling costs but may incur high costs if aerials need to be placed away from the meter for good signal strength.
Meter battery life and disposal	Where the smart metering system is for multiple utilities, the power consumption of those meters with no mains supply will be a critical factor. Typically, gas meters can only transmit data once every 30 minutes over a low power wireless link if their batteries are to have a life

	over 10 years. Any batteries fitted to meters will be subject to the Batteries and Accumulators Directive [BAD, 2008] that governs the placing onto the market of batteries and their disposal. This came into force in September 2008. Meter displays that fall within the scope of the WEEE will also fall under the BAD and must allow for easy removal of the battery at the end of the displays life. The batteries should be under the control of the meter operator and disposed of in appropriate routes. Disposal of discharged batteries will have a cost implication that needs to be considered. Permanently fitted rechargeable batteries with a power cradle will take up a mains socket and will have a higher power demand unless a high quality recharger is supplied. A mains supply would have the lowest energy consumption but will again take up a mains socket (unless fitted with its own connection, a high cost option) and will dictate the location of the meter, which won't be free to move about.
Meter and display energy usage	This is considered in ESMA Deliverable 2 [Parsons 2008] but, clearly, the smart metering system should use less power than it is expected to save. Smart metering system designers should report on the anticipated energy consumption of their systems. Those manufacturers responsible for the energy consuming components should consider where possible the use of low energy designs. Where batteries are used the comparison of energy use is more complicated than for mains power supplies as the energy costs of recycling used batteries should be allowed for. A useful report on the environmental and energy costs of batteries is given in [ERM 2006].

Issues which must be considered are:

Feedback and display to final customer considerations

It is important when selecting display technologies to consider the following points. Firstly, the MID requires that final customers have access to the data on which the bill is based. Also, the needs and types of feedback discussed in Chapter 3 "feedback" must be considered. There is currently no definitive view on how complex the display should be. Higher quality displays, with either more colours or more pixels, are more expensive but final customers are not expected to respond adequately to poor displays. Utilities will want to supply the cheapest display that achieves their objectives with regard to the final customer, especially for mass roll outs of displays. Some final customers may choose to pay more for a higher quality display, either from the utility or from an alternative vendor.

A further major consideration is the power supply to any in-house display, which will be an important consideration. There are three main options; replaceable batteries, rechargeable or single use; permanently fitted rechargeable batteries with a power cradle or a mains supply. Each of these options has some negative implications; for example, separate batteries will depend on final customers changing or recharging them with a risk of batteries being disposed of outside of approved recycling channels.

The main technical options for implementing final customer feedback include a display on a meter, a separate display device, PC, TV and a mobile phone.

It is clear that several of the issues related to effective final customer feedback involve a balance of cost and quality and that at present there is no firm understanding of where this balance should be set. It is clearly important that, until this knowledge has been developed, those designing smart metering systems should consult the literature for examples of good practice as well as carrying out consumer tests of any proposed system. Also, as knowledge is developed, it should be disseminated as soon as possible. ESMA has been established to provide this dissemination route and will provide an annual update on best practice. This leads to the following recommendations.

Examples of feedback devices

Below are shown a couple of examples of displays in addition to those already shown.

GEO – The Home energy hub is a device that uses a split current transformer to measure the current passing through the supply to the whole property. The current sensor passes its data to the display using wireless communications. In addition, this model can accept signals from gas and water meters with pulse outputs and also from plug sensors that capture the power going to individual appliances.

Figure 4-3 GEO Home energy hub

The PRI Home Energy Controller connects multiple utilities and the heating system. The controller uses ZigBee communications and the controller is certified against the ZigBee Smart Energy profile.

Figure 4-4 PRI Home Energy Controller

4.5. Recommendations

- Smart meters should contain an interface to enable the data contained in them to be communicated to other devices and systems within the home.

- This communication should be supported by the adoption of open interface and data communications protocols. The smart metering industry across Europe should agree a common approach to local data exchange with utility meters.

- The design of the WAN should allow for future growth in communication performance requirements (such as data rates, availability and speed of response) arising from the introduction of new product offerings. For some services communication availability and response time are much more critical than high data rates and the impact of these on the final customer experience should be considered at the design stage.

- As much of the cost and risk of a smart metering over its lifetime are related to WAN communication. It is recommended to pay special attention to this when designing smart metering; again considering the impact of future growth in communications.

- The security of the system must be managed appropriately to ensure that only approved parties can access the meter data and that final customers and others cannot access data within the meter that they are not approved to view.

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5. Smart metering systems - multi-utility issues

Smart metering is often synonymous with electricity metering but this does not need to be so and is not the case in the Energy End-Use Efficiency and Energy Services Directive (ESD) [ESD 2006], which covers all energy streams. This chapter examines the solutions in the field of gas and heat metering combined with water and other media consumption calculation. Extending comprehensive energy metering on different energy flows helps in improving of energy services and energy consumption improvements. The functions of multi-utility smart meters are mainly for use on Domestic Utility meters, but may be equally applicable to meters used for commercial and industrial applications.

The introduction of the ESD will cause smart meters to be an important tool for achieving the aims of the Directive. The ESD requires meters to provide time of use information to consumers as appropriate; it requires Retailers to provide “frequent” bills; and it requires energy suppliers to provide comparative information on their consumption. In order to implement these requirements and to improve their national energy systems (in terms of flexibility and efficiency), national energy regulators have studied smart metering, first for electricity (load and sourcing management) and recently for gas. Working groups including retailers, operators, final consumers are now trying to define the needs, functions and business model for multi utility smart metering. Proof of concept or products - add on or built-in - are available from most of the meter providers.

5.1. Introduction

Energy and other utilities are supplied using independent distribution networks. In most cases, metering of energy as electricity, gas and heat as well as water is based on individual, independent meters. The principle of multi-utility smart metering is to combine all the utility measurements into one device or system.

In many circumstances, a smart metering system for more than one utility, for example electricity and gas, could be more effective in influencing energy savings as well as optimising the metering installation costs and maintenance. Customers can be provided with their utilities by the same energy retailer or by different energy retailers sharing the smart metering system. There are a number of different models for multi-utility metering; the system can be operated by a single energy retailer offering multi-utility services, metering services can be provided by an external independent data acquisition company, or a single utility can offer access to their smart metering system to other utilities. Generally multi-utility metering offer a significant opportunity for reduction of operational reading costs, especially with regard to shared communications systems and customer displays. This may have the effect of bringing the benefits of smart metering to utilities that would not otherwise receive this benefit. Instead of many subsystems only one reliable system is used.

Utility meters are being transformed from simple measurement devices to complex socio-technical systems, enhanced by the addition of new information and communication capacities. The take-up of these potentials is strongly driven by the privatization and liberalization of markets. The improvements to technological capabilities and enhanced meter functionality now provide a platform for the next generation of intelligent grid and resource management regarding multi utility services: electricity, heat, gas and water. Added to the technological advances the commercial landscape of metering and meter data management is transforming as several electricity, heat, gas and water suppliers in Europe are more and more providing multi utility services.

The metering of heat, gas and water has specific aspects compared to metering of electricity. However, they share the same drivers as electricity smart metering. Water is not included in the scope of the ESD but there are equal resource concerns over water supply as with energy supply and consideration of multi utility metering must also include water.

Smart metering systems are currently available for gas, water and heat supplies. They can be operated in parallel and separately from electricity smart metering systems, and in this case become just another example of smart metering. However, they all lack a convenient power supply and must rely on batteries. With current batteries this results in a choice between large and expensive batteries with long duration or smaller, cheaper batteries and more frequent visits to replace them. This makes them uneconomic for normal residential use at present. This can be overcome by combining them with the electricity smart metering system so that they only require a low power link to the local meter hub. The hub does not have to be in the electricity meter – it can be separate.

This case has been considered in this chapter. Such systems present a number of major challenges; the collection of data from the different energy streams and the delivery of this data to different commercial parties (in liberalized markets), that is, how different retailers can share a common network.

Also, crucially for this chapter, there is a need to find a means to deliver energy efficiency and water conservation through smart metering. The advantages of smart metering and information feedback should apply equally to heat, gas and water; indeed, these streams are often larger than electricity in terms of cost and energy in the residential sector. The particular aspects of metering heat, cooling, gas and water are described in this chapter as well as how they can be combined with each other and with electricity. The chapter also considers how smart metering can be used to encourage energy and water conservation. This topic links with the content of several other chapters; Chapter 3 “The customer and smart metering”, Chapter 4 “Smart metering – technical options”, Chapter 8 “Smart metering for smart homes”.

5.2. Heat and cooling smart metering

Background to district heating (DH) and metering

Heat supply is an important sector of the energy economy in several European countries, especially in North and Central Europe. For example, in Poland approx. 50% of primary energy is used for heating purposes in all heat consuming sectors, and approximately 80% of energy consumption in buildings is provided by central heating and domestic hot water supply systems. In Europe the district energy industry includes more than 5000 district heating systems and about 100 district cooling systems. The sector accounts for about 10% of the heat and 2% of the cooling markets.

The fundamental idea of district heating is a piping network that allows multiple energy sources to be connected to many energy consumers (energy sinks). Thermal energy, in the form of hot water or steam, is distributed by pipelines from central plants to individual buildings. Energy is extracted at the buildings and return pipes bring the water back to the plants to be heated again.

Throughout the world, the main business driver for district heating is the use of thermal energy that would otherwise be wasted. In particular, district heating allows the efficient use of thermal energy from combined heat and power plants (CHP), refuse incineration plants, waste heat from industrial processes, natural geothermal heat sources, and fuels which are more easily used centrally, including renewables like wood waste and residues, as well as coal and peat.

Heat customers are connected to the network at thermal nodes. There are different types of nodes. In general they can be divided into single-function nodes (usually only space heating) and multifunctional nodes (usually space heating and hot water, but in some industrial and public facilities also ventilation or process consumption).

Heat metering is a relatively difficult process, in particular because it is performed by measuring three parameters of the heat carrier: supply temperature to the consumer, return temperature from the consumer and carrier flow rate. The thermal energy is then calculated from these parameters. The thermal energy consumed in the building is measured for billing. Consumption is shown in MWh or kWh. Normally, the heat supplier owns the metering centre.

The following data can be read from the heat meter:

- thermal energy
- volume of circulating district heating water
- instantaneous cooling of the district heating water
- instantaneous temperatures of the supply and return water of the district heating water
- instantaneous power and water flow rate

For current metering systems the final customer either sends meter readings to the heat supplier according to instructions, or the heating company reads the meter manually or remotely.

The district heating supplier provides their final customers with a follow-up report on heat consumption at least once a year. In many locations, final customers can monitor their consumption directly on the heat supplier’s website. The effect of the weather is taken into consideration using the heating degree-day in the comparison of annual consumption figures. The reports usually include adjustment to the weather. If the current consumption differs considerably from the figures for previous years, an inspection of the adjustments and condition of the equipment is advised.

A problem, associated with heat metering typically concerns costs allocation between different users of a building. Not so many years ago, in Central and East European countries, heat energy measurement supplied to individual heat nodes and buildings was a very rare situation, and settlements with final customers were conducted on a lump sum basis (proportional to the size of an area being heated or to the number of persons living there). It should be pointed out that heat losses in buildings in Eastern Europe are approximately twice as high as those in other European countries with similar climate conditions. During the last dozen or so years the thermal insulation requirements for buildings have been tightened. Today, final customers are undertaking thermal modernisation of buildings, which combines improvement in thermal insulation, installation of heat and hot water meters, installation of automatic heat supply (in heat nodes/substations) and heat consumption regulators (thermal regulators of a radiator). In Central and East European (CEE) countries in recent years the DH sector has been undergoing reconstruction with the installation of heat meters.. This process has also included economic transformation, related technical activities aiming at energy use effectiveness, reduction of environmental pollution, increase of quality and reliability of heat supply, provision of new final customer services etc. For North and West European countries this refurbishment is largely already complete.

In CEE countries a crucial parameter for the economic transformation has been energy pricing, because in the past heat prices were subsidized. Consumers covered only a small portion of heat production and transmission costs. The changes of the economic system (including reduction of subsidies) caused a rapid increase in heat prices and an ‘economic shock’ to heat consumers, especially households.

Customer payments for heat delivery were calculated in the past not on the basis of measured heat consumption, but as a ‘lump sum’ (per m^2, per person etc.). During the last three years a great effort (financial and organizational) has been made to equip thousands of substations with heat meters in all Polish DH systems. A similar situation exists in other CEE countries.

The rise of heat prices and the measuring of heat supply led to a significant decrease in heat demand. Heat consumption metering and charging based on actual supply has been the most important reason for modernizing existing DH systems with a “thermo-modernization” of buildings. This involves a reduction in heat losses and better quality services leading to a decrease in the average heat demand in buildings.

Another problem affecting the profitability and competitiveness of DH companies is the quality of heat supply control and consumers’ ability to regulate their heat consumption. This problem is connected with the measurement of heat supply/consumption as well as with tariffs and billing systems. In several countries, implementation of the automatic control of heat supply is planned, accompanied by obligatory metering and new tariffs and billing systems. These measures are expected to stimulate the modernization process both on the supply and demand sides of the DH systems.

The basic aims of restructuring the heat supply sector include:

- decreasing pollution of the environment due to an increase in the efficiency of heat supply systems (decreased utilization of fuels), substitution of fuels and elimination of furnaces and boilers that do not have emission control systems, and construction of highly efficient systems of emission control, etc.,
- increasing reliability of heat supply due to the usage of modern equipment and technology, and gradual replacement of existing equipment and installations with high failure rate, etc.,

- enabling final customers to influence a level and rational utilization of thermal energy by installing automatic regulation systems in supply and consumption of heat, as well as heat meters and limiters of heat carrier flow rate, making possible the introduction of measurement based settlement systems,
- optimizing heat supply costs by a composite modernisation of network systems enabling economic allocation of loads on heat sources supplying one network (ring network systems, microprocessor engineering, remote metering and control systems, etc.).

Smart metering in district heating and cooling systems

The basic metering of thermal nodes is essential to the performance of the district heating and cooling industry and this is the first step to be achieved. Once achieved, this industry has a significant opportunity to develop smart metering in the coming years, both in the direction of the new cooling final customers of the existing thermal heating final customers, where hot water district heating has long been employed as the preferred thermal service.

Smart meters have a strong development potential in district heating systems, in particular to provide feedback on energy use to the final customers, to communicate with the building management system, as well as the possibility to provide additional information, for example, in relation to maintenance, energy management, and security.

Moreover, the use of smart metering in district heating and cooling systems could introduce high innovation possibilities to the existing tariff systems, including the possibility to enhance demand side management and taking into account the time of day usage.

An important question to address in relation to heat metering is the heat allocation between different users/consumer of a building. Currently it is normal for heat allocation in the building to be decided at the building / housing co-operative level, while district heating utilities are responsible for heat supply to the thermal node (heat substation in the building). Metering at the thermal node is now becoming a common practice in all European countries, although only a decade ago in several Central and East European countries it was common to have district heating schemes without this basic thermal metering.

The installation of additional measuring equipment in the building for the allocation of heat consumption, for example between flats of a multi-apartment building, is in most cases a decision (mainly based on financial possibilities) of the building/flat owners (housing co-operative, “housing collective”, private company or person etc…). Very often additional measuring equipment in the building is not installed and typically costs allocation is calculated based on simple methodologies, for example heat area or heat volumes (size of the flat). A further justification of this approach is where a poorly insulated apartment block that has greater heat loss from the top and bottom floors. In this case the customers in the top and bottom floors will effectively be paying a surcharge to heat the floors between them.

It should also be noted that individual metering of heat supply to each flat with the installation of heat-meters is possible only in buildings with “horizontal” heating installations (one inlet in every flat). This type of installation is not common in existing building stock, but there are some private housing estates where buildings are equipped with “horizontal” installations.

The greater part of a heating system in the existing building stock has a “vertical” design (vertical columns supply radiators or taps water to many floors) thus in those buildings heat metering to individual flats is economically impossible.

To enable energy cost allocation to individual final customers, “heat allocation meters” can be installed on the radiators of each individual flat. In this case the heat transferred from the radiator to the room is calculated as a function of the room air temperature and the radiator surface temperature. There are several companies installing and selling “heat allocation meters”, together with reading systems and computer programs for data analysis and billing between the different building users. However, there have been cases where the installation of “heat allocation meters” has raised problems and complaints between buildings inhabitants.

In any case, it is necessary to stress that the implementation of an individual billing system in buildings needs the installation of regulating valves in each radiator (usually thermostatic radiator valves are installed).

Energy conservation in district heating

In many instances, the district heating infrastructure does not seem to allow the simple implementation of metering, let alone smart metering. However in some countries such as Poland, demand side management (DSM) has been actively developed by the owners of buildings, supported by the Act on Support for Thermo-Modernization Investment (ASTMI). The result of this DSM has been considerable with a systematic decrease in heat consumption. DSM has recently been connected with the improvement of thermal insulation in buildings as well as the implementation of automatic control for heat utilization together with heat cost allocation in multi-storage buildings. Improvement in energy efficiency in DH systems has been significant.

5.3. Gas smart metering

Background to gas markets and metering

The European gas market is faced with a major challenge: ensuring sufficient supplies of gas from outside the EU while at the same time continuing to give shape to the liberalized European gas market where the national borders within the EU no longer play a role. In the same way as electricity there are environmental and security of supply issues that require conservation of gas use. The gas market is also subject to the same market liberalization initiatives as the electricity industry, although progress varies between countries.

Smart metering for gas supply

For gas meters, smart metering is often associated with electronic meters, which are more or less equivalent to ultrasonic meters. Where new electronic meters are fitted it is possible to equip them with gas valves so that they can be remotely turned off or reconfigured as pre-payment meters, much as for electricity meters. However, ultrasonic meters have not found a large market since they were introduced to the market and the number of manufacturers supplying them seems to have decreased recently. An alternative approach is to fit mechanical gas meters with automatic meter reading facilities.

For gas smart metering projects remote communications can be provided direct to the data collectors via GMS/GPRS but this has a high power requirement leading to the need for large and expensive batteries or frequent visits to replace the batteries. An alternative and more practical solution is for smart electricity meters to be combined with smart gas, water meters via a wired or low power radio signal. This provides a relatively low cost communication system for the gas meter with a much lower power demand. A variation on this is to use a short range link to a local data concentrator and provide out bound communications through the internet. For this communication system a permanent internet connection is required. Currently about half of all Dutch households have such a connection. GMS/GPRS is a more expensive data communication system (with a corresponding negative effect on business cases), but it can be used in situations where PLC or internet communication is not possible.

A further option that is being used in many schemes at present is to use the M-Bus interface provided on the gas meter to connect to the local smart metering data system, either at a data concentrator or a suitably equipped smart electricity meter.

As for electricity, smart metering can enable demand management for gas, but it is questionable if time of use tariffs would be sufficiently different enough to influence consumption. This is because gas can be stored in the network and meeting peak demands is less of a financial penalty for suppliers.

Smart Metering system for gas

There are a number of important issues regarding the use of gas smart meters for energy efficiency and customer feedback. One area of difficulty is the application of calorific value as gas meters do not directly record energy, rather they measure volumetric flow. While there are meter technologies that can register energy directly, none have come to market in a way that can deliver real-time energy consumption, except on large industrial applications. This adds a complexity to the accurate provision of energy consumption on the meter: either calorific data would have to be available in "real time", or the meter would have to be capable of retrospectively recalculating the energy based on information when validated C.V. data becomes available. It should be noted that auditing software capable of retrospective recalculation would be a very difficult task. It should also be noted that a gas meter that estimates the energy usage and the cost for the customer will, inevitably, provide information that differs from the invoice, and therefore some customers will query the difference. In practice it may be most reliable to broadcast the daily CV for given areas.

Another major issue is that gas normally supplies only a few loads, primarily space heating, hot water and, possibly, cooking. Given the simplicity of these loads relative to the electricity demand pattern it would seem there would be little that could be done with feedback data. This is even further complicated by the demand pattern of many gas boilers that can be controlled with a simple on/off switch. This makes it very hard to make sense of the gas flow as it consists only of a series of peaks.

Energy conservation and gas smart metering

There is little current experience of energy conservation using gas smart metering. This is partly explained by the lack of smart gas meters in actual use, but also, gas loads tend to be simpler (heating and cooking) and often can be difficult to monitor with conventional smart metering displays. For instance, many gas boilers have a simple on/off control and the instantaneous gas consumption gives little idea of the actual heat output of the boiler. It is also thought that there is little in the way of direct final customer control on the heating system; it is set for room temperature and period of operation. However, gas consumption often accounts for the largest single energy input to a home and small proportionate reductions in consumption can have a significant benefit. Also, many final customers have difficulty setting their heating controls and the feedback from smart meters can assist in seeing if the controls are working as intended. Importantly, the heating system is often the most complex automatic control system in the home. Allowing the customer to see when it is operating (often when the householder is in bed or out of the home) can allow detection of wrongly set controls.

It may also be possible that the slower feedback mechanisms, such as reports on bills, can be useful for gas usage as the gas usage is limited to fewer uses and correction for factors such as degree days can produce good benchmarking. This might also be an effective means of identifying poorly performing heating equipment.

A feature of a number of new in-house displays is the joint display of electricity and gas consumption. One issue to be considered here is that final customers should be aware of the different financial and carbon implications of gas and electricity supplies. Possibly the smart metering system could provide the tariff and carbon emission factor of each fuel.

5.4. Water smart metering

Background to water supply and metering

Water is not included within the scope of the ESD, but shortage of water supply is becoming a real issue in many parts of Europe, possibly with more immediate impact than energy supply. In the same way as gas and heat meters, it is possible to combine water metering with other utility metering with the benefit of shared costs of infrastructure and the ability to combine water usage feedback with electricity, gas and heat usage.

Smart metering for water supply

There are different options for implementing water smart metering as for gas and heat metering. One key issue is that it is unlikely that the same utility supply gas, electricity and water. An example is in the Netherlands where the water utilities are considering the opportunities to use the smart metering system of the gas and electricity utility as a basis for automatic reading of the water meters. In some instances it will be possible for a single Energy Retailer to carry out gas and electricity smart metering for a single site where they supply both utilities. However, it will be seldom the case that a single utility will supply water, electricity and gas. In this case, enabling smart water metering based on other utility metering systems will depend on the development of systems that allow the different meter readings to be passed to the correct retailer.

Water conservation and smart metering

Smart metering for water has similar principles as for other utilities and relies on feedback, both real time and periodic to inform the final customer of their consumption. However, one feature of especial interest with water is that leakage within the property can be recognised and indeed detected via an alarm. Water leakage can be difficult to detect but it is shown on a consumption profile as a steady background load that can readily be recognised by the final customer.

5.5. Multi-utility smart metering

The necessary information on the technical implementation of multi utility smart metering can be found in Chapter 4 “Smart metering systems – technical options”. No consideration is given there of independent gas, water or heat smart metering systems although these are possible. However, by treating the gas, heat and water utility meters as additional meter nodes, communicating via the chosen local area network, they can readily be connected to the wide area network and in-house displays. The system protocols must be extended to include the other utility data entities (as is currently the case with DLMS) and the application layer must be able to recognize the correct destination for the data and ensure its correct delivery.

5.6. Examples of multi-utility energy displays

An example of a comprehensive multi-utility display is the ecoMeter by Landis+Gyr (see also Chapter 3 ”Smart metering and customer feedback”. It is offered as an in-home display of the metering devices. The ecoMeter gives consumers greater awareness of the energy consumption and enables them to conserve energy as well as gives energy companies new possibilities for peak demand management. It is a handy in-home display providing energy users with valuable information to monitor and control energy consumption and cost in the home. From the ecoMeter energy users can get information about their yearly electricity, gas and water consumption, greenhouse gas emissions as well as current tariff rates/demand. This gives consumers the possibility to regulate their consumption in order to save money and benefit the environment.

For energy companies the ecoMeter enables direct communication channel with their customers. It allows management of individual energy loads, tracking of export energy, account queries and scheduled outages. It thus gives energy companies new tools for leveling of the peak demand during the day.

Stadtwerke Dusseldorf is the first utility in Germany to implement an Advanced Metering Management (AMM) system with the Landis+Gyr in-home display, the EcoMeter and is doing this in order to test the viability of enhanced smart metering systems among its customers.

Stadtwerke Dusseldorf has approximately 520,000 end electricity customers in Dusseldorf and the region. It supplies electricity, gas, district and central heating as well as drinking water and incinerates domestic waste.

Uwe Schöneberg, member of the board of directors at Stadtwerke Dusseldorf said: “Our customers will now be able to analyse their energy consumption through active participation and thereby make energy savings. This contributes to a reduced burden on their finances, while also making a contribution to the protection of the environment.”

Other developments include the connection of the meter to other, multi-energy media such as gas and water, giving the customer a further insight into their individual consumption patterns.

Regular questionnaires will be sent to project participants in order to monitor how they find the new communication channels, and to analyse how this affects the usage of these channels.

The project, which is a pilot lasting one year, is being carried out in conjunction with the ministry for the environment of the regional capital of Dusseldorf, the consumer advice centre NRW and the centre for innovative energy systems at the Dusseldorf University of Applied Sciences.

5.7. Recommendations

- It is recommended to implement multi-utility meter systems with expandable data standard for each of the media used.
- It is recommended to design multi utility systems based on optimization of energy use. This shall be planned together with the DSM concept. In particular this is very important in systems with optional supply solutions.
- Regulators should consider if it is necessary to create an external independent data acquisition company for reduction of operational reading costs, rather than using a distribution system operator where energy retailers must share the system. Such systems should provide appropriate security for both the energy retailers and the customers.
- For district heating companies, the first step is to assure basic thermal metering requirement at thermal nodes and heat substation. For District heating companies there is a need to develop specifications for smart metering and identify complimentary services that can be delivered with the smart metering system.
- Careful consideration should be given where multiple utilities are displayed in the same location to ensuring that appropriate environmental messages are conveyed; for example, gas and electricity should show their equivalent carbon emissions.

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6. Smart metering and the Smart Grid

Huge investments are needed in the upcoming decade in the power sector in Europe due to the increasing energy demand, ageing generation facilities and ageing transmission and distribution infrastructure. Simultaneously the share of both Renewable Energy Sources (RES) and Distributed Generation (DG) in the generation of electricity will further increase over the next decades. These developments will have a profound influence on the electricity transmission and distribution grids across Europe. This chapter introduces the expected developments of electricity distribution grids into a Smart Grid and how this could affect smart metering services.

6.1. Prospects for renewables and DG in Europe

In the upcoming decade the energy sector - and particularly the power sector - will be affected by the transition towards an energy supply based on renewable energy sources (RES). Reasons for this transition are the need to reduce the emission of greenhouse gases, the need to secure the energy supply and the desire to become less dependent upon imported fossil fuels.

One of the main drivers for renewables in Europe is the EU and national energy policy. In December 2008 the European Council, European Parliament and European Commission reached agreement on the Energy Package, including mandatory targets for Member States with respect to the production of energy from Renewable Energy Sources [CEC 2008]. In Figure 6.1 a graph of the agreed targets per EU Member State is shown. These targets refer to the ratio between the amount of energy produced from renewables and the amount of energy consumed. They concern the average for all energy carriers and across all sectors of the economy. The share of *electricity* generated from renewables is expected to be much higher than this average. This is because it is more efficient to produce electricity from renewables than most other energy carriers.

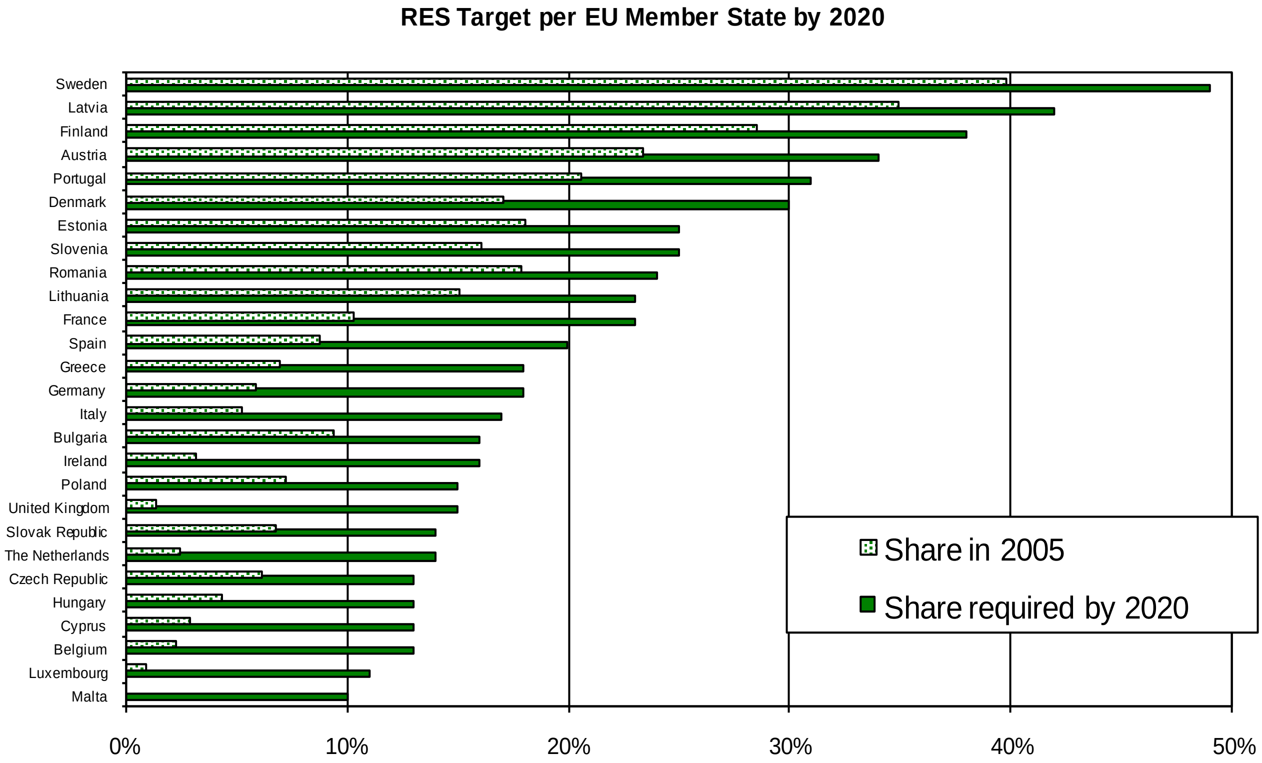

Figure 6-1 Targets for the share of renewable energy per EU Member State by 2020, compared to the the actual share in 2005 [CEC 2008].

It is not certain to what extent each of the member states will be able to reach their targets. Yet, it is clear that there is a firm commitment by Member States across the European Union to substantially increase the share of renewable energy sources within the upcoming 13 years. Simultaneously, prices for renewable energy sources like solar and wind energy are decreasing rapidly while prices for fossil fuels have become more and more volatile.

How will this affect the energy infrastructures and what is the relation to smart metering services?

6.2. The introduction of the Smart Grid

The increase of the generation from renewable energy sources and DG has major consequences for the operation of the power grid. This is caused by many factors, including the following:

- Many renewable and distributed generators are operated by final customers, rather than by professional energy suppliers.
- Many new renewable generators and all of the distributed generators are connected to the distribution grid, rather than to the transmission grid.
- The power output of most types of renewable energy sources (such as wind power, solar power and run-of-the-river hydro power) is not continuous and not fully predictable.
- Power generated from many-types of renewable energy sources is usually given priority over power generated from other sources. This is because they have lower marginal costs and less environmental impact than traditional power plants. In some countries in Europe there are also legal requirements for this.
- The number of distributed generators needed to produce a given amount of electric energy is a factor 1.000 to 1.000.000 higher than the number of large central generators.

Apart from these developments at the side of power generation, there are also other factors that influence the future operation of the distribution grids, including:

- All over Europe the electricity infrastructure is ageing. Large investments are needed to replace existing infrastructure.
- Increasing unit size of centralised generation increases demand for flexible distributed generation.
- Electricity demand will increase because of the introduction of new energy-efficient technologies. Examples are electric heat pumps, plug-in electric vehicles and plug-in hybrid vehicles. These technologies lead to a decrease of the overall energy consumption. At the same time however the demand for electricity will increase[3], and simultaneous peak demand may increase even more.

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[3] For example in the Netherlands it is estimated that the electricity consumption of an average household with an electric car will rise from 3500 kWh to almost 6000 kWh – an increase of 70% (depending upon the plug-to-wheel-efficiency of the electric car.)

In the next decades these developments call for large investments in the electricity networks around Europe. In a 2003 report the IEA estimated the investments in the power grid over the next three decades at an amount of € 500 billion[4] (roughly € 1.000 per inhabitant) [IEA 2003]. A similar investment will be needed in Europe to replace and expand the electricity generation capacity.

In view of the need for these large investments, utilities, manufacturers and researchers from all over Europe have joined forces in the EU Technology Platform SmartGrids. With support from the European Commission, this platform has formulated a common vision on the future operation of transmission and distribution grids. Starting points for this vision are that Europe's electricity networks must at the same time be:

- *Flexible:* fulfilling final customers' needs whilst responding to the changes and challenges ahead;
- *Accessible:* granting connection access to all network users, particularly for renewable power sources and high efficiency local generation;
- *Reliable:* assuring and improving security and quality of supply, consistent with the demands of the digital age;
- *Economic:* providing best value through innovation, efficient energy management and 'level playing field' competition and regulation [SmartGrids 2006].

The SmartGrids Technology Platform found that ICT and automation are increasingly becoming a cost efficient alternative for investments in grid hardware. Therefore the SmartGrids Technology Platform concluded that the distribution grid should gradually change from a passively managed grid to an actively managed grid. This means that generation and transport of power should be controlled not only at the level of the transmission grid (>= 50 kV) but also at the level of the distribution grid (<50 kV). Not only the Transmission System Operator (TSO) but also the Distribution System Operator (DSO) will perform system operation tasks. The Distribution *Network* Operator will change to a Distribution *System* Operator.

As a consequence of this, the DSO needs to control energy transports in the distribution grid. To achieve this the DSO should influence – to some extent – the generation of distributed generation units located throughout the distribution grid, as well as the energy demand from final energy customers.

All kinds of regulatory issues are still open for discussion. Questions such as: Which instruments should the DSO acquire to fulfil its responsibility towards Smart Grid Services? And which other parties should be involved in this control? A balance must be found between the interests of the final customers, the DSO, the TSO, the generators and the energy retailers. In a liberalised market model clear rules are needed to demarcate the responsibilities of each party. This might even involve the introduction of a new type of actor: the Aggregator. The role of such an Aggregator would be to buy flexibility from customers and distributed generators and to deliver it to TSOs, DSOs, as well as market parties.

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[4] The report mentions € 390 million in year 2000 euros. At an average inflation rate of 3%/year this amounts to € 509 million in year 2009 euros.

Active management of distribution grids seem far away from the current operation of distribution grids. However, over the past decades more and more intelligent devices have been introduced into the distribution grid. Consider e.g. SCADA-systems for monitoring and dispatch of the distribution grid and electronic protection devices that autonomously react to local changes in the currents and voltages in the grid. Also several experiments throughout Europe have shown that the required types of control are feasible with current ICT technology. Furthermore, rather than endangering the quality of supply, ICT technology can help to improve the overall reliability of the power supply [CRISP 2006].

Europe is not alone in developing these technologies. In the United States similar technologies have been designed and tested, within the [Intelligrid] and [Gridwise] initiatives. Both inside and outside Europe, first implementations are already taking place in specific situations where they can help to prevent or postpone costly investments in grid improvements. In 2008 in the USA, the energy corporation XCel Energy started to turn Boulder (CO) into what it calls ‘the world's first Smart Grid City’. Also the Obama administration has published ambitious plans to help introduce the Smart Grid.

Looking at that, the question is not whether or not active management of distribution grids is technologically feasible. Rather, the questions are: where will it be economically attractive to start to implement active management of distribution grids and within what timeframe and to what extent will it be introduced. Also some regulatory issues need to be solved before large-scale implementation can be expected. These include issues such as how will regulators reward investments and operational costs that DSOs make for active management, and how will time-dependent tariffs be measured and billed.

To enable active management of distribution grids cost efficiently it is necessary that the functionality and performance of smart metering infrastructures are designed to support this concept to a reasonable extent. In the next section the ICT requirements of an actively managed distribution grid will be explored further, as well as the possible convergence of the smart metering ICT system with the Smart Grid ICT infrastructure.

6.3. Functional requirements of the Smart Grid

In an actively managed distribution grid the DSO, the energy retailer and the final customer can influence the generation of and demand for electricity. In such a situation there are more requirements for metering than in the current situation. One can think of the following advanced smart metering functions:

- separate measurements for each distributed generator and each controllable consuming device (possibly depending on mode of operation of the appliance)[5]
- separate measurement of the net consumption at the Point of Common Coupling (final customer power consumption minus final customer power generation)
- feedback of these measurements to an in-home display of the final customer (or a PC or handheld device), together with reference values.
- measurement of power quality indicators.

In addition to such advanced smart metering functions, the Smart Grid contains features for the operation of the grid itself. One can think of Smart Grid features for improving:

- utilisation of grid capacity: limiting peak loads, shifting power demand;
- power quality: voltage dips and flicker compensation, damping of total harmonic distortion, 'soft' reconnection of loads after a power outage;
- reliability of supply: intelligent load management, intentional 'islanding', automated or sensor-assisted grid switching.

Mechanisms for these types of features have been and are developed and demonstrated in European research projects like CRISP, MicroGrids EU-DEEP, INTEGRAL, FENIX and ADDRESS [links to several of these projects are provided at the end of the chapter].

An important aspect for grid operation is the reliability of the Smart Grid services. For that reliability the performance of the communication channel is essential. Suppose a Smart Grid service is designed to use continuous communication and uses ADSL for communication with households. Then occasional ADSL blackouts can cause power problems for that part of the distribution grid. The utility does not necessarily have to own and operate the communication itself, but it does need to have control over its performance[6].

6.4. Integrating the smart metering system and the Smart Grid?

When considering a hypothetical 'end situation' of a grid that is fully operated in accordance with the SmartGrids vision, then some of the Smart Grid features are a logical extension of the smart metering system. Integration of the smart metering system and the Smart Grid services appears to be logical for the following reasons:

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[5] These measurements only need to be accurate for billing purposes in so far as there are special tariffs (e.g. feed-in tariffs for renewable generators.) If support for such special tariffs is not required, then these measurements can be quite simple, as they are for monitoring purposes only.

[6] Alternatively the design of the Smart Grid service could be changed to maintain operation during communication failures.

- It is difficult to separate many of the Smart Grid features from smart metering, as they are just more advanced forms of smart metering services.
- Intensified, bidirectional and automated interaction between the final customer and the grid is at the core of the SmartGrids philosophy. The smart metering system is the ICT system that is present precisely at this interface between the final customer and the grid.
- At first sight it seems less expensive to install and operate only one combined ICT infrastructure for both systems, rather than to install and operate two separate infrastructures.

Reasons like the above mentioned show that it is worthwhile considering working towards one combined ICT architecture for smart metering and Smart Grid features – at least in the 'end situation'.

On the other hand there are also reasons why it is less evident to combine the smart metering system and the Smart Grid management system:

- At the moment in most countries in Europe it has not been decided if, when and where Smart Grid features will be implemented in the grid.[7]
- The implementation of these functions is an ongoing process, which might not be simultaneous with the implementation of smart metering.
- The communication requirements for the Smart Grid management systems vary greatly from those for the 'basic' smart metering systems. Most Smart Grid features require a guaranteed response time, while the basic smart metering functions are defined such that they are less time critical. This makes it possible to use a slower and cheaper type of communication for a basic smart metering system than for a more advanced Smart Grid Management system.

Even though communication costs are expected to go down over the coming years, at the moment communication costs form a big part of the overall system costs. As long as this is the case and as long as the Smart Grid features are only required at a small minority of the final customers, it might not be economic now to install across all of the grid a communication system that supports all of the Smart Grid features.

On the other hand, one should take into account that the costs for installation of the smart metering equipment at the final customers' premises are a large part of the total costs of smart metering roll-outs. Therefore many utilities have formulated a one-visit-per-customer requirement. After the metering system has been installed, the utility does not want to return to a particular final customer until the meter will be replaced by a new one. This underlines the importance of choosing the right hardware for the smart meter from the start.

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[7] Experiences from the United States show that active involvement of regulators is needed to make it possible and attractive for grid operators to invest in Smart Grid functions.

6.5. How to prepare a smart metering system for the Smart Grid?

Below some points are mentioned that parties should take into account if they are considering to invest in smart metering.

- It is recommended to consider which functionality should be supported for new power consuming devices with potentially a substantial simultaneous peak demand, such as plug-in electric or plug-in hybrid vehicles.[8] The basic functionality for this includes time varying prices (both for electric energy and for electricity transport). Thus a *minimum* requirement is that the house has an interval meter that can handle time varying prices, so that vehicles can be charged at the house.

- Before investment decisions about smart metering are made, a vision and action plan on the transition towards a Smart Grid should be formulated. This vision and action plan should indicate if, which, where and when Smart Grid services will be introduced in the power grid and on final customers' premises.

- The ICT architecture of smart metering systems should be designed in such a way that it introduces no unnecessary barriers for a future introduction of Smart Grid services. Basic Smart Grid features that should be supported include:
    - support for time varying prices
    - bidirectional communication between the metering system and the home automation network of the final customer
    - bidirectional communication between the metering system and Smart Grid automation systems
    - export register in the meter
    - interaction with the final customer regarding the Smart Grid services.

- The communication needs of Smart Grid services should be analysed and compared with the performance of communication solutions affordable for smart metering. Smart Grid services might need instantaneous communication, e. g. to quickly balance supply and demand of power. For smart metering on the other hand interval communication can be sufficient.

- In situations in which it would require a significant upfront investment to make the smart metering system 'Smart Grid-ready' these investments should be carefully compared to alternative ways of future proofing the investment in smart metering systems. Alternatives for a full 'Smart Grid-ready' functionality include: implementing separate remote automation systems for those final customer connection points that need functionality and communication performance beyond the capabilities of the smart metering system; designing a modular system that makes it possible to individually select the functionality and performance of each particular measurement point; designing the system in such a way that it can be easily upgraded in future; and early retirement of (parts of) the system.

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[8] The metering functionality for plug-in (hybrid) electric vehicles could be implemented either using one mobile measurement unit inside each vehicle or by fixed measurement units at all of the connections used for (dis)charging the plug-in electric vehicle.

- In all situations in which an upfront investment to make the smart metering system ‘Smart Grid-ready’ does not seem justified, it is recommended to include in the design of the smart metering system at least a Smart Grid upgrading plan.

- Where metering services are highly ‘unbundled’ consideration should be given to regulatory and commercial models that allow the DSO access to the smart metering system.

- In particular one should consider how and to what extent during the introduction of Smart Grid functionalities the ICT systems for Smart Grid services will be merged with those for smart metering; or alternatively how they will co-exist alongside each other.

6.6. The communication layer

It has already been stated that bidirectional communication is necessary for the Smart Grid as well as for smart metering. Communication solutions can become a large part of the total operational expenses. Unnecessary costs may arise when later on in the project a separate communication system is chosen for the Smart Grid. Therefore the communication infrastructure of the smart metering system should be based upon open standards. This enables future shared use of the communication infrastructure for Smart Grid services, smart metering services and final customer energy management services. Also special attention should be paid at security, dependability and flexibility of the overall Smart Grid and smart metering system.

Security, dependability and flexibility of the overall Smart Grid and smart metering system are aspects that affect the choice of communication systems. They apply not only to the communication system itself, but to the overall system architecture and its operation. While the requirements for security, dependability and flexibility are already essential for good operation smart metering services, for Smart Grid services these requirements are stricter.

- Security means that no *hidden* or *unintended* side effects appear during the use of the services. For smart metering services it is e.g. important to protect metering data, to prevent fraud and to prevent unauthorized disconnection.

- Dependability means that all services are performed within the quality requirements specified. For smart metering services it is e.g. important to guarantee the timely availability of the functionalities like remote meter reading, remote disconnection and feedback of energy use.

- Flexibility of communication means that the system supports sufficient types and numbers of communication channels and protocols. This is important to be able to implement the communication links needed in a cost-effective way. For smart metering services flexible communication links are needed between all parts of the smart metering system, including: the local energy meters; the local data processing unit; the central data processing unit; back office systems of parties in the energy supply chain; and – last but not least - in-house displays and other equipment of the final energy customer.

As has been stated, for Smart Grid services the requirements on security, dependability and flexibility are in general stricter than for smart metering services. Security and dependability are more important, because the performance of the Smart Grid services is needed to guarantee the stability of the distribution grid. Requirements on the flexibility of communication are stricter because Smart Grid services require two-way communication between the appliances of the final energy customer and the distribution grid (rather than only between the meter and the distribution grid). This two-way communication between appliances of the final energy customer and the distribution grid is needed to enable coordination between these appliances and the grid, which is an essential Smart Grid feature. This requires the support of a bidirectional coupling with in-house communication systems - such as Zigbee, Z-wave, EnOcean, X10, LonWorks or KNX

6.7. Recommendations

- TSOs, DSOs, regulators should consider which functionality is needed for new power consuming devices with a potentially high simultaneous peak demand, such as plug-in electric or plug-in hybrid vehicles. Time varying prices may be the easiest way to avoid peak loads in the grid.

- DSOs, regulators and utilities should formulate a vision and action plan on the transition towards a Smart Grid, before investment decisions about smart metering are made. This vision and action plan should indicate if, which, where and when Smart Grid services will be introduced to the final customers and in the power grid.

- The ICT architecture of smart metering systems should be designed in such a way that it introduces no unnecessary barriers for a future introduction of Smart Grid services.

- In all situations in which an upfront investment to make the smart metering system ‘Smart Grid-ready’ does not seem justified, it is recommended to include in the design of the smart metering system at least a Smart Grid upgrading plan.

- The communication infrastructure of the smart metering system should be based upon open standards, to enable shared use of the communication infrastructure for services for the Smart Grid and for final customer energy management.

- Where metering services are highly ‘unbundled’ consideration should be given to regulatory and commercial models that allow the DSO access to the smart metering system.

- When designing the smart metering and Smart Grid system special attention should be paid to security, dependability and flexibility of the system.

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7. Smart metering services for demand response

This chapter considers the use of smart metering for managing loads via demand response. Demand response is strongly related to smart metering and is often treated as the same thing. Demand response can promote energy efficiency, reduce carbon emissions and depends on consumer acceptance and, as such, is an important topic for ESMA and this Guide.

7.1. Principles of demand response

One type of benefit from smart meters is the possibility of demand response.
The typical demand response is a voluntary reaction by the final customer to a price signal, e.g. delaying electricity demand by hour or two to avoid an extreme price peak. Different contract arrangements exist. The customer can have a time varying price, e.g. a day-ahead price, and can decide to adapt the electricity consumption to the prices or to ignore the prices because of more important issues. The reaction can be manual or automatic. With direct load control the customers have agreed that an external partner (utility or retailer) can control selected equipment within some agreed limits, e.g. an air conditioner can be cycled (on/off) during heat waves. Such an agreement can include a yearly rebate to balance the reduced service. The set-up can focus on anything from daily reactions to infrequent emergency reactions.

Apart from areas where there are severe supply constraints, the benefits of demand response are in general not enough to justify large scale smart metering investments alone. However demand response can be an important part of the business model combined with operating benefits, energy efficiency and other elements. Therefore it is important to consider bundling smart metering and a demand response programme together.

The value of demand response will vary from country to country. Demand response will have a special high value if peak power capacity is needed, or if the generation system is in-flexible (nuclear or coal dominated). If air-conditioning or electric heating is widespread, demand response can be an effective tool to control extensive demand e.g. during heat waves or cold periods. Because of the random nature of such weather related demand, price control of demand can be more cost efficient than investment in generation capacity. Also, variable power generation from e.g. wind power can motivate development of demand response [CRA International 2006, U.S. Department of Energy 2006, Andersen et al. 2006, and Oliva 2008].

Demand response is related to smart metering and energy efficiency improvement in three ways:

- Demand response substitutes peak power generation resources that may have very low efficiency, and therefore saves fuels. Peak power generation can also have proportionately high carbon emissions compared to base load generation.

- It has been found that loads that are displaced do not always reoccur later, thus resulting in a reduction in overall load.

- Demand response and energy efficiency require rather similar properties from the metering system. The same control system can deliver demand response and energy efficiency.

The amount of energy efficiency that can be achieved by smart metering and demand response is disputed. Capgemeni [Capgemeni 2008] indicate savings from 10 to 40%.

Experiments show that households can deliver demand response, e.g. in relation to electric heating or air-conditioning. A dynamic price signal combined with automated control of electric heating can maintain comfort at lower costs. Users can set the automatic control according to their preferences so that they do not need to respond to varying prices in their daily life.

Demand response is mostly used in relation to electricity systems (mainly because of the strict requirements of balancing short term demand and generation), however in the future similar methods can be developed for other energy systems such as district heating, natural gas and water systems.

7.2. Support for multiple types of demand response

Smart metering systems can be defined that enable several types of demand response. This will enable matching the flexibility of final customers in the most profitable way with varying situations in the energy markets and changing rules of the market. The capability to implement interval metering (to record hourly data) can be practical. In this way many types of tariffs can be applied, e.g. hourly spot prices, time-of-day tariff or critical peak pricing:

- A spot price can be a day-ahead price defined at the local power exchange. This can be an hourly price, e.g. published the afternoon the day before. The price can take any value, depending on the bids to the power exchange. Generally, prices are high in peak periods (e.g. 5-7 p.m. in a winter peaking system), but extreme prices occur irregularly when special circumstances are fulfilled (extreme cold, breakdown of transmission lines or power plants). Figure 10.1 shows an example of a spot price. Since a spot price can take any value the demand for each hour must be recorded separately.

- A critical peak pricing (CPP) is a type of time-of-use tariff where a high price can be announced when needed, e.g. a day and night tariff with an extra high price that can be activated with one day’s notice. This type of tariff more easily communicates with final customers than a spot price. The final customer has less risk with a critical peak pricing. As with the spot price the irregular pattern of extreme prices can be communicated to the user.

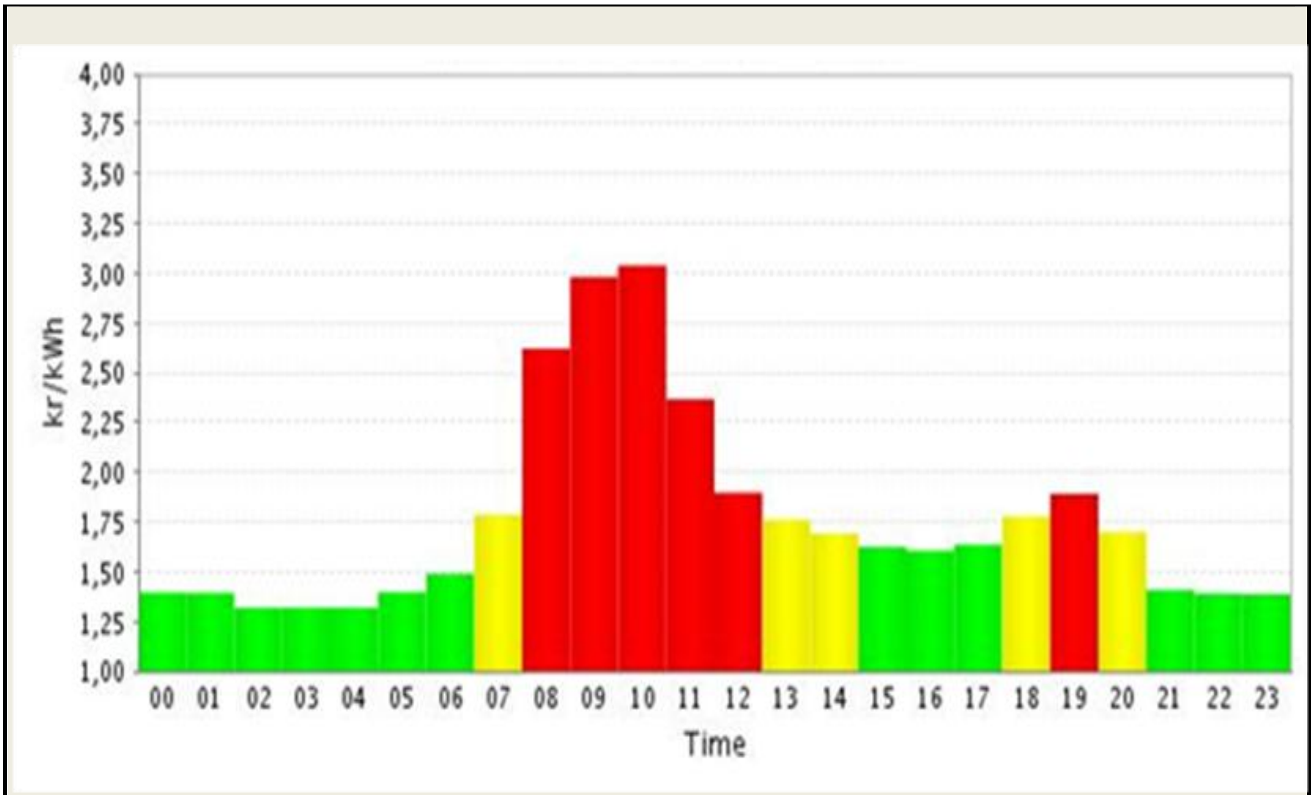
- Figure 7.1 illustrates a critical peak price. A CPP tariff can be managed by an interval meter or with a meter with a number of registers equal to the number of steps in the tariff. E.g. the French Tempo tariff has six price levels in the tariff. With a limited number of registers, communication to the meter must control how metered values are stored.

- Time-of-use tariffs (TOU) are tariffs with a fixed time structure, e.g. day and night and often combined with a seasonal structure (different definition of peak periods in summer and winter or different price levels). The tariff typically have two to six time periods and a similar number of prices. The TOU tariff can communicate the general structure of the true cost of electricity, but in contrast to spot prices and critical peak prices the rare events of extreme prices cannot be communicated. However TOU tariffs can motivate a general behaviour of shifting energy demand.

- Pricing of maximum demand (effect). In many cases only energy is measured and charged for. However a tariff with an effect element is also possible with smart metering, e.g. the maximum effect can be charged, or a maximum demand can be allowed in different tariffs (corresponding to a step payment for the maximum effect allowed).

- Direct load control will in some cases also be considered as demand response, e.g. a supplier may control air-conditioning by controlling on/off cycles, e.g. allowing only a maximum of 50% on-periods during heat waves. The final customer may voluntarily enter such an agreement and may receive economic compensation. While the price signal is not directly shown to the final customer, direct control may serve the same functions as traditional demand response.

Smart metering can be used to implement such tariffs, giving final customers the option of choosing among different tariffs as offered by the energy retailer.



Example of e-mail informing test households about high peak prices tomorrow. Colours are used to highlight high and low prices. The tariff is a spot price for energy added to a constant payment per kWh for transmission, distribution and taxes. 1 kr = 0.13€

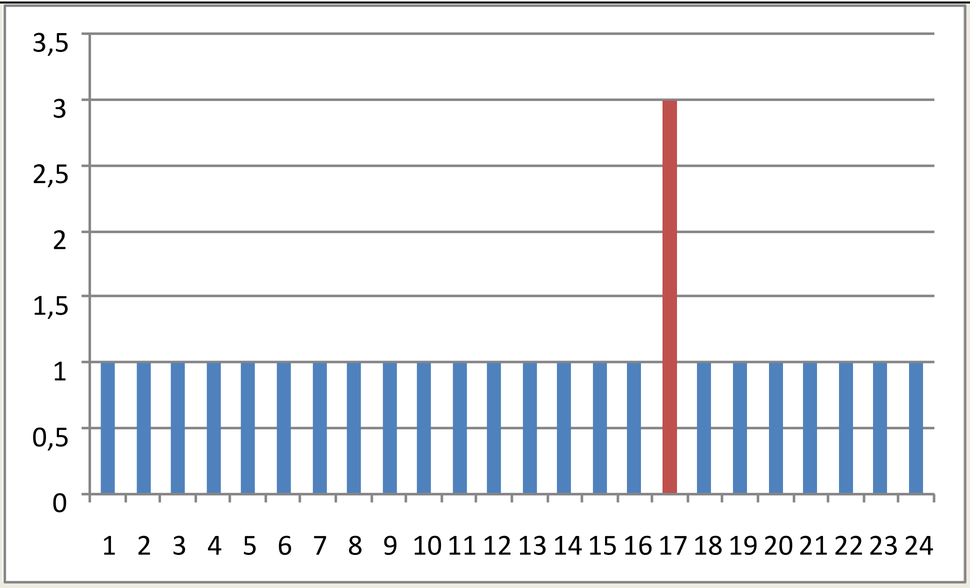
Figure 7.1 Peak price advisory email

1. With interval metering of consumption it is possible to take final customers out of the profiling system typically used for households. Whether profiling will be abandoned is a political and financial question, and in some cases profiling will be maintained for the users with the smallest energy consumption.

To benefit from prices that vary with time the final customers must have access to prices. Prices can typically be communicated though the meter, in-house display, internet, by SMS or e-mails.

Households may need some kind of internal communication system to automate the reaction to prices. This can be done by using the meter, independent of the meter, e.g. as home automation or as part of the heat control system. Utilities could consider if a local communication interface from the meter to the local control system is needed. This could transfer real time consumption data to the local system or control signals to the local energy management. In the US it is becoming common to link a wireless enabled thermostat to the meter to allow remote control of the air conditioning set point.

Feedback of consumed energy via the billing system can typically deliver data with one or two days delay. This can typically be accessed via the internet.



Theoretical example of a critical peak pricing (CPP): A constant price combined with a high price that is only activated when needed. One day notice can be given. Often a maximum number of expensive hours are promised. The French Tempo tariff (Electricity de France) is an example of a CPP tariff.

Figure 7.2 Critical peak pricing

In Finland time-of-use tariffs are widely applied and DSOs are required to support them by law. Many electrically heated houses have TOU control which has flattened the national load curve (within the order of 1,000 MW peak). Future shortages in peak power and power system emergency control resources will increase the need to use more dynamic control for electrically heated houses.

7.3. Households segments for demand response

While large industrial consumers, like heavy industry, are used to optimising production in relation to time varying electricity costs – this is not the case for households. Households with high energy consumption are probably the most interesting household segments for demand response. Households with electric heating, heat pumps or air conditioning can be interesting segments. These users have a high electrical consumption, which makes potential savings more interesting. Also, the type of end use (heating and cooling) is suitable for demand response. Due to the thermal inertia of the building the energy demand can be disconnected for one or two hours without major comfort problems.

Gaining customer acceptance of schemes is critical to their success. Customers can dislike automated schemes where they sense that they have lost control of their home. This can be influenced by cultural factors, the marketing of the scheme or the level of incentives offered.

7.4. Estimating the benefits

Estimates of likely benefits are needed to justify and design investments in demand response and smart metering. Estimating the benefits of demand response can be split into estimating the value of response and estimating the size, dynamics and reliability of the response. It is also necessary to understand the tariff variations that customers need to motivate them to join a scheme or respond in a dynamic scheme. This can prove a challenge.

Estimating the value of demand response on the basis of past energy market prices does not give an accurate view of the value of demand response in the future, because the future prices and need for generating capacity may be different from the past. When demand response is applied in large scale it reduces the price variations in the market.

It is useful during planning to compare demand response with alternative ways of making the same necessary peak power investments to the system. Depending on the characteristics of the supply and demand such alternative investment can e.g. be a gas turbine.

Both field tests and simulations are typically needed for the estimation of the size and dynamics of the response. Field tests are necessary for estimation and verification of the simulation models. Simulations are needed to compare alternative approaches in various scenarios of future prices.

7.5. Recommendations

- When preparing for the roll out of smart meters, demand response should be included in the cost benefit calculation
- Relevant design features related to demand response should be included in the meter requirements. These include the time resolution of the metered values (days, hours, quarter hours or minutes) and the feedback and communication possibilities.
- Utility planners should be aware that the need for demand response may be different in the future. Tight capacity balance, more local generation or more wind power may increase the benefit of demand response.
- The acceptability of the scheme to customers should be considered and tested through field trials.

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8. Smart metering services for smart homes

Both smart homes and smart meters are promoted for the energy savings they can bring about in the home. Although they can both work independently, it is clear that combined they may provide even greater energy efficiency benefits. This Chapter looks at how smart homes and smart meters can be combined to promote enhanced energy savings and other benefits.

8.1. The Link between smart metering and smart homes

Smart homes technology, like smart meters, has many applications and is difficult to define. The BEAMA Smart Homes Group [BEAMA 2007] has divided the various applications into four categories:

BEAMA Definition of Smart Homes Technology

GREEN SMART HOME

Allows the householder to reduce their impact on the environment by providing energy usage information, control strategies and automated operation of products.

SAFE AND SECURE SMART HOME

Enables householders to be more secure in their homes via security products allowing for increased user interaction, more remote controls and monitoring, internet use and other communications methods.

ASSISTED LIVING SMART HOME

Has features enabling householders to enjoy, and remain longer in their homes, irrespective of age and disability.

LIFESTYLE SMART HOME

Possesses products with functionality to provide lifestyle benefits including intelligent entertainment systems and on-line on-demand services.

Of these the first, Green Smart, is most relevant to the aims of ESMA and will be examined in detail within this chapter. However, both “Safe and Secure” and “Assisted Living” could interact with smart metering systems. The lifestyle smart home may provide opportunities for new feedback paths for smart meter data. Indeed, there is mounting concern that the energy demands of modern and future lifestyle equipped smart homes may add substantially to future energy demand growth. It would be fitting if green smart homes, linked to smart meters, could reverse this increase.

The key elements of the green smart home are the heating control system, individual appliance controls and house sensor and control networks. Primarily smart home controls and sensors allow heating controls to minimise the energy input to the heating or cooling system whilst satisfying the comfort requirements of the occupants. The smart homes components can all be linked together to optimise the operation of the heating system by, for example, reducing the temperature in unoccupied rooms, either pre-programmed or in response to occupancy sensors. The operation of appliances can be timed to minimise the peak house power demand or to exploit time of day tariffs (see Chapter 7"Smart metering services for demand response").

The aim of smart metering, as defined by ESMA [Koponen 2007], is to provide final customers and other parties with information to reduce their peak or total energy demands. Smart metering also creates a communication channel between the energy retailer or other authorised body and the final customer. The information stream from smart meters can be fed to the smart homes Home Appliance Network (HAN) to increase energy savings. Additionally, the communications channel can be used to pass information between the energy retailer or ESCO and the smart homes system, to extend the control over the home. Additionally, it is possible for smart meter and smart home systems to share components, such as communications links. Below, a number of opportunities are identified that arise from linking smart homes and smart meter systems.

Improved house monitoring and feedback

Smart homes technology can be used to gather data from appliances and link to carbon and cost data from the smart metering system so that the financial or environmental cost of running individual appliances can be seen. Also it can provide additional information about appliance usage to combine with the overall energy consumption data from the meter to give a much richer understanding of energy usage and, consequently, greater ability to control and reduce it. Finally, it can allow the smart homes system to compare energy and water consumption to expected levels given the operational status of the home and trigger an alarm when abnormal operation is observed. An example of this is the PRI Home energy controller [PRI, 2008]. Smart metering can also assist with a new challenge facing householders. There is a potential downside to the increasingly sophisticated control of home heating. Advanced controls can minimise the energy consumption of homes but, if poorly set up or maintained, they can increase energy consumption by, for example, turning on when their is no one present. An important function of smart metering will be to allow customers to view their energy demands and to check that their controllers are operating as desired. Regarding the previous example, this would allow householders to see the on-off times of heaters and to check that these fit with the intended control pattern and the occupancy patterns,

Demand response

The smart homes network can be used to allow individual appliances to be controlled in response to signals from the energy retailer or Energy Supply Company (ESCO). This could be much cheaper than installing separate control circuits in the home. Indeed this function is strongly linked to demand response technology, dealt with in Chapter 7 "Smart metering services for smart homes". Indeed this is the area that has seen most application, especially in the US, Canada and Australia. Various schemes have been introduced where the power utility can remotely adjust customers' air conditioning thermostat for short periods to avoid power peaks. A number of different communications protocols have been introduced to support this interface; such as the ZigBee smart energy profile and the Z-Wave protocol and appropriate thermostats are available for purchase. In theory, this approach could be extended to smart appliances and heating thermostats. The equipment to implement this does exist and there are available smart power switches that fit between the appliance and power socket. These can be used to turn on and off any connected appliance. It would appear, though, that there has been little development in linking these switches into a smart system with utility control in Europe.

Enhanced heating controls

Weather forecast data could be passed to the central heating system so that heat input can be brought forward or put back as appropriate. Where there are choices over where energy can be drawn from, for example heat from gas or electricity, or the carbon content of an energy stream varies over time; such as electricity (where, for instance, the proportion of fossil and renewable generation input varies), the control system can optimise for these, rather than to simply minimise the energy input.

Safe and secure smart home

Smart homes can provide enhanced intrusion detection. The usefulness of this depends crucially on a secure communications link out of the home. Normally this uses the final customers fixed telephone line but this is often physically vulnerable, compromising the security of the system. Access to a separate, secure and universal communications route could be of great value to security system providers.

Assisted living

There is growing interest in the use of techniques to remotely monitor people in their own homes who would otherwise need residential care [Telecare]. As the number of elderly people increases and pressure on residential care places grows, this becomes ever more important. Assisted living takes two forms, passive monitoring of the frail (so that an alarm is raised if they have a fall) and active monitoring of the sick (so that doctors can monitor their vital signs remotely). Both of these services currently exist and do so without any use of smart metering systems. However, both applications depend on secure communications channels. Where smart metering is implemented to support multiple energy retailers offering individual utility contracts, these systems will feature secure communications channels and strict control over the destination of messages to ensure that they are delivered to the correct address. This feature could be of considerable benefit to assisted living providers as they would be relieved of responsibility for this channel (especially as sometimes there is no existing fixed telephone line in the property). Exploitation of this secure communications channel might even justify the use of multi-user systems even where there was only one energy company.

8.2. Meeting the needs of smart homes with smart meters systems

To enable these opportunities and link smart homes and smart meters, the main requirement is to establish a secure data link between them, a common data subset and to provide control over the destination of messages passing between the systems. HAN networks are likely to have their own connection to a WAN link and there is the possibility that these could be shared with a mutual cost benefit. This, however, may compromise the universal approach to smart metering if billing data can travel via different routes. It may be that energy retailers and ESCOs could use both links to the home as part of different offers to final customers, one limited to billing, the other (via a broadband link) allowing more advanced services. It may also be possible that smart metering systems could be designed to recognise the existence of high speed links and to use these when possible.

The link between the systems must meet a number of critical requirements.

- Enable a secure, 2-way link between the smart homes HAN and smart meter systems. Such links must be controlled so that only authorised parties can make this connection. Messages must be able to be directed to specific recipients and be shielded from all other users of the system.
- Provide access to consumption data from the meter, identifying different energy steams and measures.
- Provide access to tariff and other energy descriptions; such as price and carbon content.
- Support communications between the smart homes system and the remote energy retailer, ESCO and other authorised parties.
- Support future innovation in both smart home and smart meter technology and applications.

There is no essential need to combine the smart home and smart meter systems into one unified network, as it is possible for them to operate in parallel and just to supply a data bridge between the networks. The cost of such bridges is falling and should not be a barrier to linking the systems. This approach would much reduce the difficulty of reaching agreement on a common system that would have to meet the needs of many stakeholders. It is likely that this link will be achieved by the use of a Standards based approach, coming from liaison between the smart metering and smart homes communities. Such standards do not currently exist but work on them has begun. The Application Home Initiative [TAHI] has started a project in the UK. This is linked to a CENELEC smart homes project. A number of other data exchange protocols have been developed by groups around the world and links to some of these are given below. The ZigBee and Z-Wave protocols both support smart meter and smart home interactions. A further programme of work is the Internet for Smart Objects that aims to provide a protocol that will extend IP to all intelligent devices, such as smart meters and smart home devices.

In the absence of such standards it is recommended that systems implemented include a number of features:

- Protocols and data sets of early smart metering systems should be extensible so that they can be extended and enhanced as new applications are devised.
- Systems should allow negotiation of a communications channel so that lower cost and faster channels can be utilised if available.
- Systems should be devised so that approved users can conduct secure 2-way communications with arbitrary devices in the home.

It is clear that the nature of smart home technology is rapidly evolving. This must be allowed for in the development of protocols for smart homes and smart metering. In all likelihood, the way to achieve this flexibility is to include in data protocols undefined data exchanges between the systems that can be used for future needs.

8.3. Examples of smart homes linked to smart metering

PRI Home energy controller

Figure 8-1 PRI Home Energy Controller

The PRI Home energy controller is of note because it links smart metering functionality (the ability to collect data from the electricity, gas and water meter) with the heating control system. At this time, the main advantage this provides customer with a much improved view of the energy usage and cost of the heating system. However, the controller is certified against the Zigbee home energy profile and can link to thermostats, so that, in theory, the system can be further enhanced. These devices are being tested in the UK EDRP Trials.

Tendril Insight in-home display

Figure 8-2 Tendril Insight in-home display

The Tendril Insight is a ZigBee enabled display that connects to other ZigBee devices that, combined, can form a smart home network. The Tendril is currently being used in smart metering schemes in the US.

8.4. Recommendations

- Real time access to consumption data directly from the smart meters to the Home Area Network (HAN) should be provided.
- Agree a communications protocol between the smart meter and smart homes systems. This should be supported by the provision of hardware bridges to provide a connection between smart meter LANs and Smart home HANs if a common system is not used.
- Ensure that approved agents can make use of the smart meter communications link to pass data to smart homes devices. This would require the negotiation of a commercial basis to cover the cost of the communications service.
- Ensure that smart metering data protocols make provision for passing through messages relevant to smart homes applications.

8.5. References

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[Telecare]	The Telecare Services Association, 10 Railway Street, Chatham, ME4 4JL, UK http://www.telecare.org.uk
[TAHI]	The Application Home Initiative, http://www.theapplicationhome.com

9. The utility and smart metering

Smart metering is a mixed blessing for utilities; it can transform their business but also promises to reduce their energy sales. The purpose of this chapter is to show that improving energy efficiency and customer feedback can benefit utilities and that utilities can have an important role in improving energy efficiency.

9.1. Impacts of smart metering on energy distribution and retail

Smart metering can significantly influence the way that utilities function. It can not only help to automate the meter reading process but also enables the modification and efficiency improvement of other business processes of energy retailers and Distribution System Operators (DSOs). At first sight the prospects for energy retailers and DSOs arising from reducing customer energy consumption are negative as their revenue will be reduced. However, smart metering introduces a number of new opportunities for utilities to reduce their costs of operation, to improve their operation and service and to introduce new product offerings for their customers. The retailers (RESCs) especially can build new business and improve their competitive position based on lower sales of energy. This chapter presents these possibilities, both positive and negative, and also looks at what effects smart metering may have on other stakeholders such as providers of Energy Service COmpanies (ESCOs).

The variations in market design and responsibility for meter operation across Europe make it difficult to accurately identify which market actors will actually benefit from features of smart metering. When considering and implementing smart metering it is necessary to take into account the utilities and their benefits. In most countries the distribution network operators are responsible for metering. Much of the potential benefits from smart metering go to distribution network operators and energy retailers.

Table 2.1 in Chapter 2 “Why smart metering” provides a full list of benefits arising from smart metering. Of these a number provide immediately benefits for the operation of energy distributors (DNOs) and energy retailers. They both can interrogate meters on demand and can swiftly and accurately deal with customer queries, for example about bills, offers, faults or energy consumption. This should reduce the costs of maintaining call centres and improve customer satisfaction. In competitive markets, where the cost of winning new customers is significant, there are major financial benefits to the energy retailer in avoiding the loss of dissatisfied customers.

Remote control of the meters (where a switch is included in the meter) provides a further benefit through the capability to re-connect or disconnect customers without manual, local intervention. New customers or customers with unpaid bills may be serviced accordingly with minimum labour costs just from the dispatch centre. This provides the RESC with new means to manage customers in debt, traditionally a disproportionately high cost part of their operation. Utilities can also use smart metering to uncover and reduce fraud.

Timely data allows simplification of ICT processes and enables accurate knowledge of the network situation and market balances. The introduction of smart metering can be accompanied by a complete revision of the IT infrastructure of the utility with major benefits from the use of state of the art system design and technology. It follows from this that the introduction of smart metering is a major decision, not just for the metering department but for the whole of the utility

The energy retailer or DSO may also choose to move their residential metering to an interval basis, where the consumption is recorded at frequent intervals between 5 minutes and an hour. This move is being made, for example, in Ireland as part of their implementation of smart metering. Availability of such interval data is an important contribution to the introduction of flexible time of use tariffs and also allows the energy retailer to better understand the consumption behaviour of their customers. This enables them to make better, more economic, energy purchasing decisions as a result of more accurate prediction of the energy balance and thus, reduced hedging costs.

9.2. New market opportunities for RESCs

The previous benefits are real and significant but largely allow the utility to perform its current business better. However, advanced metering infrastructure introduced to small-scale customers, i.e. households and SMEs, may offer more than this; it can open up new opportunities for products and services. It can be seen as a dedicated gateway to the customers' home, offering additional energy related services from which both customers and energy retailers may benefit. These benefits are examined below.

Energy efficiency

With growing calls for giving customers feedback on their energy consumption *"frequently enough to enable them to regulate their own consumption"*, as it is stipulated in the EU legislation [ESD 2006], smart meters are the tools which may fully meet these requirements at affordable costs. Smart metering should provide customers with information on their consumption that lead to overall energy savings.

There is a wide-spread fear among energy retailers that the introduction of smart metering will cut their revenues and profitability (due to lower revenues and the substantial investments in smart metering, which may not be recovered under the present business scenario). However, smart metering can bring about significant changes in the near future in the scope and character of the service of energy supply.

While today the main concern of the utilities is "only" the reliable supply of energy (of different forms), tomorrow will also add responsibility for the provision of energy services to realize energy savings as the ESD prescribes (it instructs member states to oblige energy retailers and distribution operators to offer - directly or indirectly - energy services which will lead to verifiable and monitorable energy savings).

The pre-condition to this is receptive customers willing to modify their behaviour in favour of lower energy use (or willing to be persuaded). This behaviour can be developed through well-targeted information campaigns and the introduction of further stimuli (like reward for the protection of the environment) which will incite customers to take the desired actions. But experience suggests that the motivation towards energy savings must be "refreshed" on a permanent basis otherwise the effect of more cautious energy use may erode over time. It can be expected that, in order for energy savings to be realized, financial incentives (possibly state-supported or mandated) will also be introduced to make energy efficiency measures more attractive in economic terms. Energy savings will thus acquire additional monetary value which can be assigned to the party which is responsible for the savings.[9]

More efficient use of energy (i.e. providing the same level of comfort with a lower amount of energy) can be accomplished by providing customers with the right feedback on energy use, in the format and extent that will be understandable to the customer and will include easy-to-follow recommendations/actions (see Chapter 3 “Smart metering and customer feedback”.)

Potential energy savings, which may arise from the provision of effective feedback, have been demonstrated in numerous trials [Henk Van Elburg 2007], and are a primary reason for ongoing public debates on the mass introduction of smart metering in many countries. However, it must be stressed, that it is the instrument of EUMF (End Use Monitoring and Feedback as a package) that will be needed to bring about energy savings and not the technology of smart metering itself. The energy retailer will be required to supply the other elements, such as publicity and guidance, either itself or in collaboration with energy agencies and other suitable agents.

It must be stressed, however, that the provision of this information is, in itself, a new product offering from the energy retailer to the customer and can, in principle, earn revenue for the energy retailer. In competitive markets, energy retailers may be able to compete over the feedback mechanisms that they offer and differentiate themselves from competitors.

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[9]) It must be noted that motivation towards energy savings will be to some extent downgraded by the functionality of dynamic pricing, if introduced along with smart metering. Charging different prices during different time periods will result into bigger differences in unit prices, especially among those customers which use electricity for standard purposes (lighting, running appliances) and those who use electricity also for hot water preparation and/or heating.

This will result in an unwanted distribution of price (dis)incentives among end users for realization of energy savings – those who use less will have higher unit energy price than those who use much more.

Thus, one kilowatthour of energy consumed/saved in a household of the first type may be priced as much as several times more then one kilowatthour consumed/saved in the latter one which use energy on much larger scale.

The ultimate solution to this is the expression of used (and saved) energy in terms of environmental impacts which accompany its production & supply, such as carbon dioxide emissions. Thus, energy savings achieved by final customers with higher consumption levels would be further rewarded by seeing also reduced negative environmental impacts. Both energy savings and simultaneously avoided environmental impacts may both be metered (accounted for) and further communicated to the end consumers as well as other parties.

Additionally, the fast progress in digitalization of homes introduces market opportunities for provision of other ancillary services by energy suppliers like securing remote control and operation of not only heating and cooling systems but also of other equipment (e.g. white goods, office equipment etc.), and delivery of useful information customized for specific types of customers (e.g. on air-conditioning for customers who may be considering their purchase). Then, utilities may charge some additional fee for these services offsetting any decrease in revenues arising from selling lower amounts of energy (see Chapter 8 “Smart metering services for smart homes”).

Other advanced services, which may be introduced by or along with smart metering technology can also be reflected in marketing communication strategy of energy suppliers towards customers and be used to revise the attitude of customers towards energy retailers. Therefore, an indispensable part of the launch of smart meters shall be marketing activities directed at final consumers to explain:

WHY a smart meter is beneficial
WHAT functionalities is to bring and
HOW these can be used for their good (e.g. to lower their present energy consumption)

Demand Response

Demand response is dealt with in detail in Chapter 7 “Smart metering services for demand response”. However, as it represents a major prospective benefit for energy retailers it is discussed briefly here from the perspective of a market opportunity for the energy retailer. Demand response arises primarily from the possibility to control when and how much customers use energy. Demand response for small-scale energy users is not yet presently a common practice, but would be enabled significantly by smart metering.

Basically, there are two major instruments which energy retailers can offer to their customers:

- variable pricing schemes
- load control devices

Especially where the energy retailer is purchasing power in a competitive market, there are major financial benefits to the energy retailer if it can avoid the purchase of high cost (and often high carbon) peak load supplies. These savings can be passed onto customers to mutual benefit.

Utilities have a number of options with regard to how they introduce demand response, largely depending on the degree to which they give customer control over the system and careful consideration must be given to the financial deal offered to the customer and how it is marketed to them. The introduction of time varying and dynamic pricing can be accompanied by the installation of remote/automatic load control devices/programs. This can maximise the desired load reductions and avoid the need for the customer to take any action.

The typical end uses which may be subject of such remote switching/control are space heating and cooling (or generally “conditioning”) systems or water heating. More advanced load control programs may also regulate lighting sources and more intensive electric appliances with adjustable time of operation like washing machines and dishwashers.

To minimize the intrusiveness of the automatic load regulation programs to acceptable levels, the customers are usually given the right to define, or at least be informed in advance, when load control would be introduced. The conditions may be defined in the form of the (projected) mid- or peak times, by the maximum price level above which the load control may be introduced or by the permissible number of interferences during a given period. The last two types of introduction of load control were, for example, applied in the ADRS Trial in California [ADRS, 2004].

Other potential revenue steams

There are a number of possible further new revenue streams arising from smart metering technology. These primarily exploit the smart metering communication channel. For instance, it would be possible for a meter operator to offer to other utilities access to the communications network, either utilities in competition with them or offering different utilities. It would be reasonable to expect that the meter operator should charge a rent for such services. Other customers for the communications channel might be found; for example in Chapter 8 “Smart metering services in smart homes” it is suggested that providers of home care services might be attracted by the security and ubiquity of smart metering communications and might be prepared to pay for access to it.

There are a number of issues related to this potential income stream, for example, regulators might be concerned that the meter operator had unfair access to this network although this might be dealt with by regulating access or allowable rents. Also, customers of the meter operator would need to be confident that their data was confidential and secure.

9.3. Impacts of smart metering on ESCOs and market operators

Smart meters may be a highly desired instrument for energy services companies (“ESCOs”) which are seen as one of the key players contributing to the energy reduction goals as projected by the EU Energy Services Directive. Their existence may also extend the energy savings among smaller energy users from both the tertiary and even the residential sector since smart metering infrastructure may offer detailed monitoring and feedback information provision at low operational costs.

Energy retailers have so far found that energy service contracts are unprofitable, largely because the margins on such contracts are insufficient to support the effort required to sell them to customers. Smart meters may facilitate the operation of energy service contracts and alter this economic impasse.

However, it must be stressed, that a key precondition to the achievement of energy savings is to accompany feedback information on actual energy use by targeted energy advice which will inform the end user how (in)efficient their home and equipment presently used there is.

Thus, ESCOs, or in general, suppliers of “negawatts”, will have to come up with a customized approach towards those end customers who energy services are to be provided to. They will also have to develop effective know-how for assessing the potential of energy savings and how to achieve their ultimate realization with the help of appropriate motivation instruments.

The extent and successfulness of providing such energy services will largely depend on the legislative framework established at the European or national level for their promotion. An obligation on energy retailers or other actors to deliver a certain amount of white certificates annually via a white certificate system, , may be necessary to support such a market.

A promising support to this that has been proposed may be to give energy savings, and (higher) energy efficiency generally, an attractive “brand” [IEA DSM-Task VII 2003]. That would attract a significant number of customers’ responsive to such values and help drive a market transformation.

9.4. Utility financial analysis for smart metering

The economic efficiency of smart meters has so far been the subject of various studies and pilot trials. In one of the most recent analyses [Eoin Lees Energy 2007], carried out in order to consider the introduction of smart metering technology in the UK, the annual financial benefits for energy suppliers and distributors were studied. The potential benefits which would result, largely from cost reductions in meter reading, management, and maintenance, were assessed at about 10% of the initial capital costs (which included the capitalized costs of stranded assets i.e. the residual value of the existing meters that were replaced while still not fully amortized), ICT, and installation).

However, it is clear that all market actors will carry out their own financial analysis and it is recommended that these are thorough. The economic case for the introduction of smart metering technology is highly specific depending on the local prices of the products and services concerned (energy to be saved, labour, metering equipment), scale of smart metering introduction, and also the requirements of an investor on the rate of return. However, as the opportunities for new revenues arising from smart metering systems are developed and better understood, this should add to the economic case for smart metering and provides a promising “up side”.

When assessing the economics of smart metering, it is important for the utility to consider the revenue and costs from additional services they can sell to customers. The utility faces risks in doing such decisions as development of competing alternative services and regulation are difficult to predict.

9.5. Future developments

It is likely that this is an area where there will be many and unexpected developments as energy retailers will have a high incentive to develop new products based on smart metering. This probably includes many areas where it is best to leave the market to develop its own solutions so as to avoid limiting opportunities. However, it is also likely that the regulators and consumer bodies will need to monitor developments to ensure that the customers’ interests are always considered.

9.6. Conclusions

Smart metering introduced to small-scale customers, i.e. households and SMEs, may offer more than just remote reading and controlling capabilities. It can be seen as a dedicated gateway to the customers’ home, offering additional energy related services that may benefit both customers and utilities.

However, the introduction of smart metering to households and small-size businesses requires concerted action from all the market players in order that the potential benefits are harnessed to their full potential. Unless such a coordinated approach is taken interested parties, such as utilities, may be exposed to costs without a corresponding counter value.

9.7. Recommendations

- Any plan for smart metering introduction should be designed based on a profound cost-benefit analysis to avoid or diminish potential negative financial impacts.
- Regulators should ensure that smart metering is introduced in such a way that it supports a market for new ESCO products.
- Any implementation of smart metering should be accompanied by proper promotion activities directed at final consumers to explain why a smart meter is beneficial, what functionalities it is to bring, and how can it be used for their good (e.g. to lower their present energy consumption and energy costs and improve their comfort).
- Improved ability to influence consumption patterns of the households thanks to smart metering may lead to better load management and overall energy reductions, but will also improve distribution and retail operations.

9.8. References

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10. Determining energy efficiency gain using field trials

This chapter will outline the efficient design of smart metering field tests. The aim is to promote a common European approach towards setting up Smart Metering Field Trials, in order to make it possible to exchange results from trials across Europe and to exchange hard won best practice in running trials. The description will include common guidelines on how to determine the energy savings attributed to smart metering implementation. The chapter is targeted at bodies seriously interested in the energy efficiency impact of smart meters. This can be a regulator that sees energy savings as an important argument for the investment in smart meters, or an energy company active in promoting energy savings.

10.1. The Challenge

Smart metering can have several benefits. One of these is that smart meters can be used to give feedback to final customers about their energy consumption, and this can lead to greater awareness about their energy use and potential energy savings. The potential for energy savings can be expected to be different from one final customer segment to another and from one country to another. The current literature throughout Europe gives mixed results about the possible savings. Therefore it can be relevant to perform field trials to test innovative combinations of smart meters and feedback mechanisms. Often utilities use trials to assess the energy savings that they can expect from implementing smart metering and this figure can be an important factor in justifying (or not) smart metering and for allocating the contribution of customers. However, a trial of smart metering is a difficult exercise

- Utilities can have a large number of options for feedback and each needs to be the subject of a statistically valid trial.
- Teething problems of a technical nature can intrude and change the customer’s experience.
- Energy usage is subject to change owing to price variations, weather patterns and regardless of whether there is smart metering or not.
- Achieving a good impact on customer’s energy usage through smart metering requires major promotion to the customer, this can influence those not involved in the trial.

Designing trials that accurately predict the result of a mass market roll out of smart metering is a major challenge.

10.2. Feedback systems

Metered energy consumption can be presented to the final customers in many ways. The meter can have a display, or other media can be used, e.g. SMS, e-mail or tables and graphs on an internet home page. Or the feedback can be combined with the energy bill, e.g. in form of printed information. The feedback can be automatic and periodic, e.g. each day, each week or each month. It can be activated by the user and it can be combined with other types of information, e.g. comparisons with similar households or with relevant energy saving information [Fischer 2008, Darby 2006, Ueno 2006]. See also Chapter 3 “Smart metering and customer feedback” in this guide.

The possibilities are many, and probably different end-user segments will prefer different feedback systems.

10.3. Known field tests

Practical tests in relation to feedback systems can have different purposes. They can be field experiments with the purpose of documenting the effect of feedback in a scientific setup, or it can be to model projects with a more practical purpose of a general testing of a feedback system [Fischer 2008].

Many field tests have been performed, but only a few deliver significant results concerning energy savings from feedback systems. Many of these tests have a variety of objectives – to document energy savings from feedback has only been one such objective. Other objectives have been to test the technical capabilities and performance of the equipment, as well as initial testing of the user interface.

An example of a strong design is an ongoing Danish experiment [Kibsgaard 2008, Gleerup 2008]. It is a research project funded by the Danish electricity utilities. Three features make this design strong:

- There is a reference group and an intervention group (318 households in test group and 417 in reference group)
- There is one year of measurements before the intervention starts.
- Socio economic data will be merged to the database from the national statistics (including number of people, age, education and income)

These three features combined with the size of the experiment (in total 735 households) will make it possible to exclude the impact of external influences, e.g. from weather, economic growth or national events. Furthermore the plan is to set up an advanced statistical model with strong characteristics. The model can take into account unobserved individual differences by attribution of an individual level of consumption to each household. This makes the estimation of the impact of the feedback more efficient. Review of the experiment indicates that an even larger sample size would have desirable.

In many other cases the results have not been significant. This could be due to small impact on energy efficiency or to an inadequate design of the field trial. A poorly designed field test can, e.g.:

- A too small sample of final customers. With a too small sample, data noise and external changes not related to the experiment will disturb the results. Several experiments include less than 120 households and produce only vague results [Fischer 2008].
- Have no reference group. Without a reference group (or control group) general changes in energy consumption will disturb the results. The general changes can be influenced by weather and economic growth or new prices or taxes. With a reference group the impact of a general trend can be subtracted from the data and the impact of feedback can be isolated.
- Be planned without considering social or cultural factors that may affect the outcome, and need to be taken into account when selecting participants and conducting the trial.
- Have no ‘before’ measurements. Without before measurements it can be difficult to calculate energy savings.

- Not allow for the fact that the final customers may change their behaviour because they know that they are being observed –the 'Hawthorne effect'. Are the results due to the feedback of information, or are they a side effect of the extra attention related to the experiment?
- Not last long enough. The long term reaction to feedback can be very different from the first reaction. When electric heating, air condition or other seasonal activity is involved it is important to observe for one or more seasons.
- Teething problems with equipment can affect the experience of customers and change their response.
- Fail to correct for self selection of trial members. Often those who want to be involved are motivated by energy savings, have already made energy reductions and can mis-represent the general public.

With one or more of these flaws it can be difficult to obtain significant or reliable results. Establishing whether small savings have been made is a particular challenge. While it is relatively easy to demonstrate significant results with 10% savings – it is much more difficult with e.g. 1% savings. Small savings are easily lost in the uncertainty introduced by noise or improper design. It is important to consult a qualified statistician when planning your trial, at the earliest opportunity, to make sure that the trial will be powerful enough to do what you require of it.

The ideal – that seldom can be reached

In the ideal set-up for a field test the participants for the test group and for the reference group can be freely selected. They can be selected in a way such that the two groups are equal regarding all important aspects, e.g. energy consumption, types and size of house, number of people and types of energy consumption. If a sufficient number of households could be attached to each group it would be simple to document the energy savings related to the feedback: One could simply compare the energy consumption in the two groups (test group and reference group) and the difference would be the savings that could be ascribed to the feedback. The provision of feedback is the only difference between the two groups.

However, this ideal setting can seldom be realized. There are several typical reasons for this, e.g.:

- Usually a field test is voluntary. The test group will typically have the right to say yes or no to participate. When this is the case *self selection* takes place, and this will disturb the design. The yes-group will be different from the no-group, e.g. the yes-group could have a majority of young people or well-educated people. Whatever bias the self selection group will introduce, the test group will now be different from the reference group. Therefore methods must be used to separate the self selection effect from the feedback effect.
- Often the reference group comes out different from the test group. This can happen when participants are not selected completely randomly, but are taken from different locations. Even two different parts of the same town are likely to produce different groups. Often little information is available when selecting members of the two groups. An energy company may only know the address and the historical energy consumption. While the historical energy consumption is central information, other information may be needed to build comparable groups. The same electricity consumption can be found in two households – but with and

without electric space heating or water heating. During a mild winter the two will react differently.

Sample size to overcome random variation

Large variations take place in the energy consumption of individual households. When little information about the households is available these variations seem random. See Figure 10.1 where 41 seemingly identical households are followed for four years. It should be obvious from the figure that a small sample (e.g. less than 10) would not produce good results.

When deciding the sample size the natural variation and the size of the expected savings are important. High variations as well as small savings require large samples.

Also, it is important to know if the results should hold for the entire group, or if subgroups with high savings should be identified. Often a certain choice of feedback mechanism attracts most attention from certain subgroups, and therefore it can be relevant to identify these. Then the sample size must be high enough to identify such subgroups.

As a rule of thumb, it can be indicated that a sample of at least 100 households is needed in each group (test group and reference group). These sample values hold when medium to high savings are expected (3-5%). If only small savings are expected (e.g. 1-2%) the minimum sample size must be increased to 500 or more. Smaller savings than 1% can be extremely difficult to document with significant results.

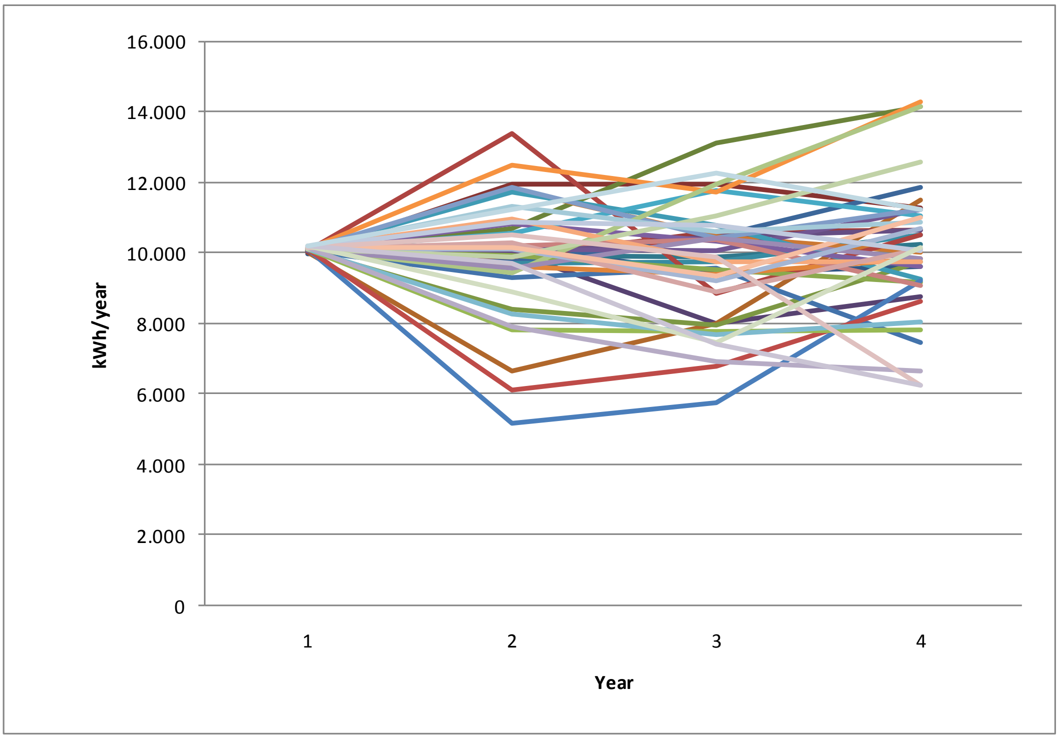

Figure 10-2 Demonstration of natural noise. Here electricity consumption is shown for 41 households for four years. The users have been selected from a larger data base and all have a consumption between 10,000 and 10,200 kWh/year in year 1. They are all houses with electric heating. Note how the consumption varies with time. While the average all have a consumption between 10,000 and 10,200 kWh/year in year 1. demand is changing less that +/-4%, the individual consumptions are changing +/- 40%.

10.4. Which information to include?

It is obvious to include the energy consumption in the data base when studying energy savings – but which other information should be included? Three groups of information can be considered:

- Information to describe reasons for self selection. This is important if the results shall be used to predict the impact of a full scale program. Information can include income (or a proxy for this, e.g. size of dwelling), experience with the internet (if this medium is used for feedback), age and family size. Note that it is important to have information from all groups, including those who refused to participate and the reference group.
- Information to describe variation in energy consumption (before test). This can include type, age and size of dwelling, energy appliances (special focus on appliances with a high demand, e.g. electric heating, tumble driers, swimming pools, electric water heating)
- Information to explain variation in energy savings due to feedback. This can include how often individuals have used the feedback, and if they have realised major energy savings in the study period.

These data can be collected by questionnaires (sent by mail, e-mail or collected by phone) or in some cases statistics exist. Where displays are supplied button press counting can be used to measure their use.

10.5. Aggregation of data

Often the studied information is the aggregated energy consumption of a test group compared to a reference group. The data can be expressed as the average energy consumption per household.

However, it should be carefully considered if the evaluation should be performed on data before the aggregation. By maintaining data for the individual households several alternative ways of analysing exist. With data per household subgroups can be studied. In many cases the overall result of an experiment is limited and often not significant. But quite often a subgroup can be defined that has produced significant results. The feedback mechanism may be more attractive to young people, or households with old appliances. Also, results improve when data can be controlled for relevant information. If the number of people living in the household has changed during the test period, this will influence the energy consumption. Correction for this will give more accurate results.

10.6. Statistical methods

When self selection exists or when the expected energy savings are limited, statistical methods must be used to obtain significant results. Regression analysis is one such method often used. E.g. a logistic regression analysis can describe the self selection process of accepting or refusing to participate in a test. With this method a probability of saying yes can be calculated for each participant. By including this information in the database the impact of self selection can be studied along with the impact of the feedback.

A linear regression is an equation, where, e.g. the energy consumption is explained by a number of variables.

Energy consumption = $+ \alpha_0$
$+ \alpha_1$ * Size of house

$+ \alpha_2$ * Number of people living in house
$+ \alpha_3$ * Group

In this example Group is a so called dummy variable, which has the value 0 if the observation refers to a member of the reference group, and 1 if it is from the test group. A standard spreadsheet program (e.g. Excel) or a specialised statistical program (e.g. SAS or SPSS) can solve the regression analysis. This includes finding the four values: α_0, α_1, α_2 and α_3. The coefficient is easy to interpret: α_0 is constant; α_1 describes the impact of one extra m^2; α2 the impact of an extra person. The impact of the feedback is α_3.

Information from the program will indicate whether each of the coefficients is significant. Depending on the sample size and the design of the model a maximum level of significance of 1 or 5% is often used. With more than 100 observations a level of 1% should be used. Only coefficients with significance below 1% should be considered.

To be successful an appropriate model must be developed. This requires that the relevant information is present and that the model is developed with care. The more variables included in the model, the higher the share of the variation the model can explain. However, it is important to keep the model as simple as possible. A model with too many variables may be “over estimated” which will result in less accurate results. With too many variables the coefficients for some variables may “drift”.

10.7. Other methods

It is highly recommended to study the energy consumption directly when the task is to document energy savings due to feedback systems. Reliable metered data should be available when studying smart meters.

Alternative methods of documenting energy savings include engineering methods. With engineering methods the type and number of energy efficiency actions are described and a standard value or a calculated value of energy savings is attached to each activity. By providing the same information from final customers without feedback (a comparison group) the savings related to the feedback can be calculated.

The method is best to include the impact of technical projects (e.g. purchase of new appliances or building improvements). Behaviour changes are unlikely to be calculated with high accuracy. With realised energy savings in the order 1% this method cannot be recommended.

In the course of the implementation of the Directive on Energy End-Use Efficiency and Energy Services, default values might be developed (see www.evaluate-energy-savings.eu).

10.8. Recommendations

- Include a control group and a before period, if possible
- Trace selection process
- Combine electricity consumption data with data, e.g. from questionnaire or existing databases
- Involve a 'social' person from the beginning of the planning, to check that relevant social and cultural issues have been taken into account in selecting participants and carrying out the trial.
- Remember the 'Hawthorne effect' and allow for it.
- Involve a statistician from the beginning of the planning process
- Consider using statistical methods, e.g. regressions analyses to document impact
- Consider keeping data as individual data, e.g. per household
- Look for sub groups with high savings – as a supplement to the study of average impact
- Only start with a field test if significant results are expected
- Smart meters, ICT and communication systems may increase electricity demand. To be effective the energy savings realised by final customers must outweigh this extra consumption. This additional load should be accounted for in the energy saving analysis of the field trial.

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11. Metering and regulation

This chapter presents a summarised overview and analysis of regulatory and market conditions for smart metering in a selection of European countries. The scope of the chapter does not include technical barriers such as interoperability of meters or communication protocols (dealt with in Chapter 4 “Smart metering systems – technical options and Chapter 12 “Smart metering systems – standardisation”). This Chapter uses regular definitions of electricity market bodies, which are adopted and used by the European Commission (EC 2006/32, 2006). Mandatory implementation of smart metering in the distribution of natural gas, water and district heating is still very limited in Europe. Therefore this chapter concentrates mostly on smart metering in the electricity sector. A comparative overview of legal framework related to gas and electricity metering is presented in [ERGEG 2007].

The main data input to the task has been gathered from a survey of Regulators and Electric Utilities in ten European countries [Morch 2007] and supplemented by the project partners and other open information sources, including web, periodicals and comments from the members of the ESMA Alliance. According to these inputs, the Regulators’ responsibilities in general and their role and involvement in implementation of smart metering in particular differ significantly between countries in Europe. Therefore the chapter is intentionally generic, so that it can be applied to most European countries. However the conclusions may not be universally relevant to all European countries.

11.1. European regulatory context and the role of national regulation

The two recent European directives: 2004/22/EC on measuring instruments (MID) [2004/22/EC] and 2006/32/EC on energy end-use efficiency and energy services (ESD) [2006/32/EC] are important with regard to implementation of smart metering in Europe. The first states metrological requirements for metering instruments, while the second links energy metering and billing to energy saving and thus requires provision of accurate metering, timely billing based on actual consumption and sets requirements for provision of information to the final customers. This directive also required member states to draw up, by 30 June 2007, national action plans (NAPs). In October 2007 the Commission has emphasised the importance of this Directive by launching infringement proceedings[1] against 12 member states for failing to deliver NAPs.

It is however necessary to mention that these directives identify only some functional requirements to metering of energy consumption. None of these directives refer directly to the expression smart metering or its most commonly used synonyms, even though some of the functionality mentioned in ESD in practice can be achieved only by using smart metering. Even though the term smart metering is frequently used today; there is no commonly agreed and concrete definition of smart metering, its scope and functionalities in Regulatory framework. Accordingly, there are no clear definitions of the different attributes of smart metering, for example, the quality and reliability of it, which makes it difficult to set precise requirements for smart metering. Development of more elaborated and clear definitions of terms related to smart metering is one of the outputs of ESMA [Koponen 2007].

The importance of national regulations in the implementation of smart metering is doubtless. In 2007 the Norwegian Regulator (NVE) pointed out that there are many reasons to believe that after a period of time existing electricity metering and communication equipment will be replaced by modern AMR/AMM solutions [Fossdal 2007]. This is likely to happen even without implementation of specific requirements from the Authorities. At the same time, involvement of Regulators in the process and the imposition of functional requirements will help to avoid potential pitfalls during the implementation process and thus make operation of smart metering equipment more beneficial for society.

11.2. Types of regulation across Europe

Based on the results of the surveys and additional information sources, three different types of regulation requirements were identified related to smart metering of Final Customers in Europe: mandatory requirements, no requirements and voluntary installations. National regulation regimes usually combine several of these: mandatory requirements, for example, can be applied to one group of Final Customers and No Requirements and/or Voluntarily Installations for the remainder of final customers. This classification does not consider unbundling and liberalisation of metering activities, as was done by the European Regulators Group for Electricity and Gas (ERGEG) in their recent report [ERGEG 2007]. In practice none of the countries (except UK), which participated in the project's survey, have unbundled or liberalised the metering activities. Furthermore, at the time of writing this Guide, the project has not received any signals about concrete intentions for unbundling of metering activities in the surveyed countries, even though it has been suggested in some publications [ECON 2007].

Mandatory requirements (M/R)

Mandatory requirements demand implementation of energy metering, which will meet a requirement of a given frequency of meter reading (hourly, monthly etc.) for a certain group of final customers. Grouping of the final customers can be related to:

- Their size, usually described by their energy consumption (kWh) or capacity (size of the main fuse in Amperes)
- Their connection to a network level (feeding voltage)
- Possibility of feeding into the distribution network (own power generation)
- Installation of new meters or replacement of old ones

The mandatory requirements usually come into force from a specific date.
Examples:

- From 2005 in Norway all final customers with an annual consumption larger than 100,000 kWh have to be metered hourly. Additionally, all installations, which feed electricity into the distribution network, have to be metered hourly.
- In Spain hourly metering is compulsory for final customers with voltage over 1 kV and electronic meters are required for all new installations after 2007.

Indirect requirement (I/R)

The main difference from the previous one (M/R) is that the responsible bodies are somehow encouraged to implement smart metering, even though it is not directly required by the Authorities. The encouragement can be done by authorities via economic regulation of DSOs (where relevant), which will simplify recovery of the initial investments or even direct subsidies. (It has been commented several times that it is difficult to design a regulation regime which will create equally strong incentives for all bodies [ECON 2007]).

The encouragement can also have a “bottom-up” approach, when the final customers are allowed to demand installation of smart metering from the responsible body in order to achieve more correct billing and invoicing.

Example: Final customers in Norway may require installation of smart metering from their local DSO if they are willing to pay the installation themselves. The maximum price ceiling is legally set by the Regulator to app. 300 Euros per final customer (costs of meter and its installation).

It is necessary to mention that the mature deregulated electricity market environment with frequent pricing of electricity and switching of electricity suppliers provides strong incentives in itself. The responsible bodies choose to install smart metering voluntarily in order to reduce costs for metering, settlement and billing and also to improve relations with the final customers. These incentives can be further enhanced by the Regulators by imposing rules on shorter switching times of electricity suppliers and more frequent billing (based on actual meter reads).

Example: In Finland hourly electricity metering has been installed to hundreds of thousands of final customers, which lay below the official mandatory threshold for installation (see Table 11.1). In Sweden, several DSOs have chosen to install hourly metering for all final customers even though only monthly reading is required from July 2009.

The incentives are not always very clearly expressed and may be difficult to identify, but voluntary installations of smart metering by utilities will normally indicate their presence. It means in general that potential benefits from installation of smart metering for a given DSO become higher than the expected capital costs.

No requirements (N/R)

Several countries, participating in the project indicated that there are no requirements for smart metering of final customers in distribution networks. However, the final customers may be required to manually read the meters relatively often. In these countries the deregulation and unbundling processes were recently initiated and are still in progress, so there is no an obvious need for frequent metering of energy consumption.

Example: In Latvia there are no requirements for smart metering of final customers. Customers read the meters manually once a month.

The following Table 11-1 presents an indicative overview of smart metering regulation in Europe.

Table 11.1 Examples of smart metering regulation in Europe

Country	**Type of regulation**
Poland (PL)	N/R
Portugal (PT)	N/R
United Kingdom (UK)	M/R: 0,5 hour resolution for final customer with capacity over 100 kW
Norway (NO)	M/R: one hour for final customer with a consumption larger than 100.000 kWh pr year (proposed for all from 01.01.2014) I/R: weekly or hourly metering for the rest. (The regulations specify periodical reading (mainly self-reading) every month, every second month or quarterly.)
Spain (ES)	M/R: one hour for final customers with voltage more than 1 kV M/R: for all new installations (number of daily periods to be defined)
Latvia (LV)	N/R
Denmark (DK)	M/R: one hour for final customer with a consumption larger than 100.000 kWh pr year. I/R: for the rest
Sweden (SE)	M/R: monthly for all final customers from 2009 M/R: hourly for final customers with a main fuse over 63 A I/R: hourly metering for all final customers
Finland (FI)	M/R: hourly for final customers with a main fuse over 3x63 (required only for those 3x63 A final customers that participate in the competitive electricity market or who make a new network contract) I/R: hourly metering for all final customers
The Netherlands (NL)	M/R: monthly for final customers with capacity over 3x80 A (a two-phase mandatory introduction for all customers is under discussion)
Italy (IT)	M/R: Gradual implementation of smart metering (hourly metering for final customers with capacity over 55 kW by 30.06.2009, interval metering for final customers with capacity less than 55 kW by 30.06.2012)
Czech Republic (CZ)	N/R

Challenges in implementing smart metering

One of the main concerns is the issue of so-called stranded assets, related to the replacement of the old electromechanical meters. These meters have a lifetime of approximately 25-30 years and are difficult to utilise after their replacement. This is especially important in the countries where a considerable part of the housing stock is new. It is possible to reduce the significance of the problem by a gradual introduction of the smart meters, where the Smart Meters will be first used in new installations during the first implementation.

Example: In Spain installation of electronic meters first has been required for all new installations (after 2007). In Italy the implementation plan is scheduled until 2012 with no compensation to DSOs for stranded assets [Villa 2008].

One of the main unresolved issues related to the implementation of smart metering is that several market bodies are expected to receive direct or indirect benefits from the mandatory implementation of smart metering [Parsons 2008]. At the same time the meters' capital and installation costs are normally solely covered by a local DSO or another body which is responsible for the metering. Several examples of cost/benefit analysis point out that it is difficult to identify and quantify all the expected benefits [ERGEG 2007

Implementation of smart metering on a big scale is a very long and costly process, requiring considerable capital expenditures from the responsible market bodies. Accordingly, it was pointed out by almost all the responding utilities [Morch 2007] that high investment costs expose the responsible body to considerable financial risks both during the implementation, commissioning and regular operation period. The type of Regulation can probably create more favourable conditions for reduction and diversification of the different risks but it is difficult to find an immediate solution to this problem without a comprehensive study.

Preparation and installation of smart metering is very time consuming. When a single country implements a mandatory requirement for implementation of smart metering within a relatively short time period, it may easily create a shortage of smart metering equipment on the market and cause unnecessary complications for the process. Installation of smart metering requires the skilled manpower necessary to replace the meters. If the implementation period is short and/or several DSOs are running the process simultaneously, it may create serious problems due to limited availability of competent vendors, adequate metering systems, expertise and access to local manpower. Against this must be balanced the desire for utilities to avoid an extended operation of parallel systems and the need for full implementation before some benefits are achieved. Rapid implementation also causes future problems as the meters reach the end of their lives and have to be replaced, repeating the previous installation peak or raising costs by taking meters out of service early.

Functional requirements

In [ERGEG 2007] it is recommended that the regulator in a country sets minimum functional requirements for meters installed – in order to ensure a certain standard of data quality and functionality within a certain area or country. Implementation of such minimum functional requirements will secure functionality of the Smart Meters and reduce risks related to potential technical and business issues, as for example interoperability of meters and the software. Normally these requirements are related to performance and functionality of the metering equipment rather than to specific hard- and software specifications. The functional requirements should support implementation of the ESD Directive providing a sufficient technologic base for implementation of future energy -efficient products and services as, for example; time-sensitive pricing and customer feedback (see Chapter 3 Smart metering and customer feedback).

Example: In its recent draft document the Norwegian Regulator (NVE) in suggests requirements about possibility for registration of outages and using external equipment as consumption displays with Smart Meters [NVE 2008].

The mandatory functionalities should be coordinated with other relevant Authorities, for example, Office of Weights and Measures (technical requirements) and Data Inspectorate (data security and privacy issues) and other legal acts and technical norms. Finally, it is natural to expect that after a first full-scale implementation, new and improved functional requirements will be introduced within a reasonable period of time.

11.3. Organisation of the market and smart metering

Deregulation and incentives

Deregulation of energy markets receives additional benefits from smart metering and increases the incentives for its implementation. Before deregulation, when national electricity markets were dominated by regional electricity monopolies and the electricity tariffs were more or less constant, there were no strong needs for smart metering for small final customers to facilitate the market. The deregulation process introduced competition into several segments of the market and particularly between electricity producers and retailers. The electricity is priced on national or regional Electricity Exchanges, where the wholesale price is defined by market equilibrium between supply and demand. The market-based pricing of electricity on the deregulated markets requires complicated and costly settlement procedures, which are necessary to secure the possibility of changing electricity retailers and ensuring competition between them.

The survey, conducted by ESMA [Morch 2007] showed a broad variation of driving forces, related to the implementation of smart metering. These variations are evident, both between different market bodies in a country, as well as between the same bodies in different countries. The main conclusion was that certain driving forces have been initially created by the deregulation process. Furthermore these driving forces are likely to evolve and become even more important when the deregulated markets become mature. It was, for example, mentioned earlier that utilities in countries with deregulated markets have to face very demanding billing and supplier-changing procedures (imposed by the Authorities) and therefore they consider smart metering as a very important tool for improvement of these.

Table 2.1 in Chapter 2 “Why smart metering” summarises national stakeholders and their incentives. Depending on legislation, organisation of national electricity markets and responsibilities of different bodies, the list of stakeholders and their incentives may vary from country to country.

Utilities will implement smart metering subject to the currently prevailing regulatory and commercial situation. Under current conditions in many markets, this may not give adequate functionality and interfaces for the future needs of unbundled markets. It will be the role of regulators to consider the future requirements of competitive markets and ensure that smart metering systems are designed appropriately.

When it comes to voluntary installations of smart metering, it is necessary to keep in mind that a future introduction of mandatory requirements on the given market may have retroactive demands for functionality of meters, for example, metering frequency. Changes in the regulation are particularly important to optional functionality, for example, metering of voltage or provision of burglar alarms services. These functions may become less beneficial than was initially anticipated if unfavourable requirements are implemented during the lifetime of these meters.

Unbundling models

The deregulation and unbundling models as well as their implementation paths differ significantly across Europe. It has been pointed out earlier that metering and billing are not parts of a natural monopoly environment of electricity distribution networks [ECON 2007]. Therefore these activities can be separated from the operation and maintenance of distribution networks and exposed to competition. The issue of unbundling is described in details in ERGEG's report [ERGEG 2007].

Example: Liberalisation of some metering activities (installation, operation and maintenance) has been implemented in Germany in 2005, while the rest of the metering activities are expected to be liberalised later.

The survey, which was conducted in the project earlier, points out that there are several different ways to define responsibility for metering and metering assets.

- In many countries DSOs are responsible for the metering of electricity consumption and billing of the networks services. Metering and billing can often be outsourced to external bodies (Metering Operators), but DSOs will still be responsible for this.
- In UK after deregulation the Electricity Suppliers have become responsible for metering and are required to contract with a meter asset provider, a meter operator and a data collector.
- In the Netherlands Final Customers are responsible themselves to choose and engage a Certified Metering company. This model has however had certain limitations and is expected to be changed on 01.01.2010.

11.4. Recommendations

Authorities:

- It is important to identify an optimum detailing level for the Regulation: poor, overly complex and unpredictable regulation may have negative impacts on the implementation of smart metering and reduce the expected benefits.
- Implementation of minimum functional requirements, which are most relevant for the given country (-ies), would secure sufficient functionality of the Smart Meters and reduce potential technical issues and business risks.
- The energy efficiency can be improved by providing the final customer (and other actors) with access to metered data giving a consumption feedback and supporting development of new products and services
- The functional requirements should be coordinated with other relevant Authorities, for example, Office of Weights and Measures, Data Inspectorate (data security and privacy issues) etc.
- Risk of stranded assets can be reduced by gradual implementation, starting with new build installations.
- The implementation schedule should not create organisational and logistical bottlenecks due to lack of equipment or skilled manpower

Utilities:

- The cost/benefits analysis should consider the possibility of future changes in the national Regulation regime, which may increase or decrease the value of both core and additional functionalities.
- After the first implementation, new and improved requirements can be introduced within a reasonable period of time. This has to be considered during initial design of the system with regard to flexibility, compatibility, standardisation and modularity.

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12. Smart metering systems – standardisation

The introduction of smart metering has the potential to bring hundreds of millions of new meters into use across Europe. It will introduce new functions such as local and wide area communications between the meters, local displays, other utility meters and the remote data collector. Smart meters may also introduce new data items, data flows and new business processes, such as dynamic tariffs and multi utility data flows. Smart metering systems will also interface with customers, smart homes applications and smart grids. The meters, display devices, communications and other devices will be produced by many manufacturers to be used by many utilities working under a wide range of market conditions. There will be multiple software applications from those embedded on the meters through to the back office. All of these components must work together correctly and reliably in parallel and series as appropriate. To achieve this it is essential to develop a comprehensive interoperable environment for smart metering. Such a system should be based on international standards and this chapter examines the topic of standards.

12.1. Introduction

Briefly, a standard is “a document, established by consensus and approved by a recognized body that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context. Standards should be based on consolidated results of science, technology and experience, and aimed at the promotion of optimum community benefits “[CENELEC 2002].

Any organisation looking to implement smart metering now will look to see what standards are available to support smart metering. They will find that standards have been developed for various aspects of smart metering of which some are country specific and that there is no complete, unified set of standards that covers all the aspects of smart metering for all market conditions and applications. They will also discover that certain aspects of smart metering (such as, and critically for this Guide, final customer feedback) are still being developed and may not yet be developed enough to allow standards to be defined. Thus the question is raised, how should the organisation deal with standardisation; should it wait for standards to be developed or proceed now and work to its own methods? This chapter examines the options for the use of standards to support the implementation of smart metering and considers what such standards should contain. Especial focus has been given to the aspects that affect final customer response most strongly.

The topic of standardisation is complex and an introduction has been provided in Appendix 2. This is included because it is likely that Standards will be developed for smart metering at some time in the future and how this will happen is partly dictated by the procedures and rules of standards development. Standards -or the lack of them, have a critical impact on the development of products and services for final customer feedback and energy efficiency. Suffice to state that the development of smart metering standards in Europe is likely to be international and require cooperation through the main European standards bodies; CENELEC, for electronic and electrical aspects, ETSI, for communications and CEN for all other aspects. The standards will also need to comply with relevant European Directives such as the Measuring Instruments Directive (MID) [MID 2004]. Smart metering may also be subject to the Services Directive [SD 2006].

The purpose of this chapter is to highlight the aspects of standardisation that are most relevant for improving energy efficiency and final customer feedback with smart metering.

12.2. Legislative environment

Smart metering will be subject to a number of regulatory pressures, both local and European. The major European Directives affecting smart metering implementation are the MID, ESD, the Services Directive.and the Public Procurement Directive [PD, 2004] Some relevant aspects have already been mentioned in Chapter 11 “Smart metering and regulation”.

Measuring Instruments Directive

The prevailing New Approach Directive relevant to utility metering is the Measuring Instruments Directive [MID 2004] that was implemented in member states in October 2006. This sets the minimum essential requirements for fiscal meters and, for utility metering, has a similar market scope as the Energy Services Directive [ESD 2006]. The MID only addresses the metrological aspects of the meters, for example, setting minimum accuracy levels and the quantities that should be measured. Other functionality aspects of meters are not covered but, where relevant, they must not interfere with the metrological operation. It is illegal under European law for member states to impose additional requirements above the essential requirements of the MID. This will constrain the ability of Governments or national regulators to mandate detailed technical requirements for smart meters. However, purchasers of meters are free to specify additional meter functionality.

A series of harmonised standards have been published by CEN and CENELEC that can be used to demonstrate compliance with the MID. It should be noted that for electricity meters, the MID only lists active energy, kWh within its scope, so it is not allowed to add a national requirement for other quantities, such as reactive power for electricity metering below 100kW supply as this would be beyond the minimum essential requirements of the MID. An important note from the MID is that the metrological features of the meter must not be changed once the meter has been put into use. Thus, any later change in meter firmware must not impact on the measurement functions of the meter as this would invalidate its original approval.

This issue is part of an ongoing discussion between national governments and the Commission. It has become very clear that a major element of any solution to this issue will be reference to European Standards. This greatly increases the importance of the timely development of appropriate European standards. And also, it might be mentioned, the relevance of this chapter.

The Services Directive

A further Directive that may be relevant to smart metering systems is the Services Directive [SD 2006] that comes into effect in December 2009. The purpose of this is to open up service industries across Europe in the same way that the New Approach opened up product sectors. The implementation of the Services Directive is still being worked out but it may apply to applications such as billing software and other final customer facing services. One area under active consideration is Module 6 – Billing and innovative metering practice [CHESSS 2007]. It is clear from the scope of Module 6 that these activities will be highly relevant to developments in smart metering, if they are taken further. The CHESSS project has been concluded now and the final report is progressing through review.

The Procurement Directive

Where smart metering equipment is purchased by a utility this may fall under the Procurement Directive. This Directive sets out to ensure an open market and makes specific reference to the use of European Standards in forming the technical requirements of any tender. Where metering has been unbundled and the meters are provided by an organisation that has no public licence to operate, then they may no longer be governed by the Procurement Directive.

12.3. Smart metering networks

A smart metering network can be seen simply as a specific example of a distributed data network. There are various models used to describe such networks but for this study the 5 layer model seems appropriate [Tananbaum, 2003]. This is a hybrid of the ISO 7 layer model and the TC/TCP model an is shown in Figure 12-1.

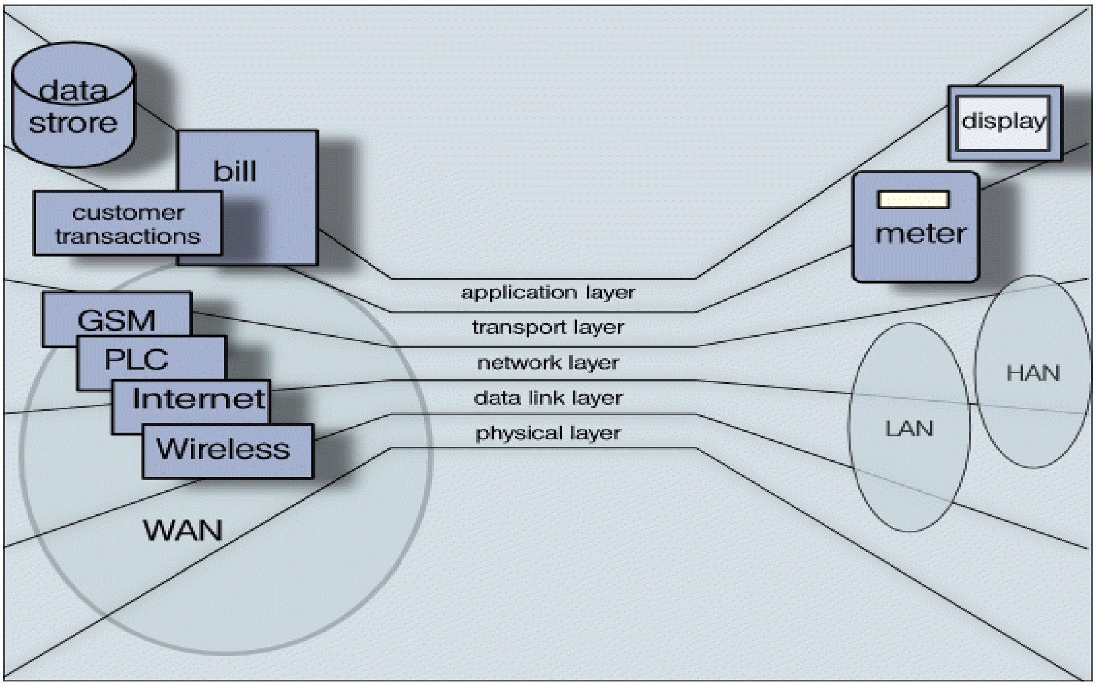

Figure.12.1 Smart meter network layers model

With all such network models the idea is that each layer provides a specific set of services for the layers above and that each of the layers should be able to ignore what goes on in the other layers. Hence, the application layer will pass a high level command, such as ‘read meter number 128638’ and this instruction is passed through the lower layers until it arrives at meter 128638, which responds by sending back its meter data. It should be clear from this that it is vital that the system can contact the correct meter, that the command is properly understood by the meter, that the data is properly understood when returned and that it is not scrambled and is secure. The data will travel over a number of different networks encoded in different formats. Unless a complete system provided by a single vendor is used, such a system can only be implemented if based on common standards. However, the special challenge for smart metering is that it, potentially, links together a large number of distinct networks. This is described in the next section.

12.4. Scope for smart metering standardisation

A complete smart metering system has considerable scope for the use of standards because it links a host of different network types, so that each network must be individually specified and also their interfaces. Likewise, data must be able to travel from one network to another without losing its meaning or being corrupted. Linking the networks and their associated devices should also not lessen the security in the networks being linked. The possible linkages are shown in Figure 12.2

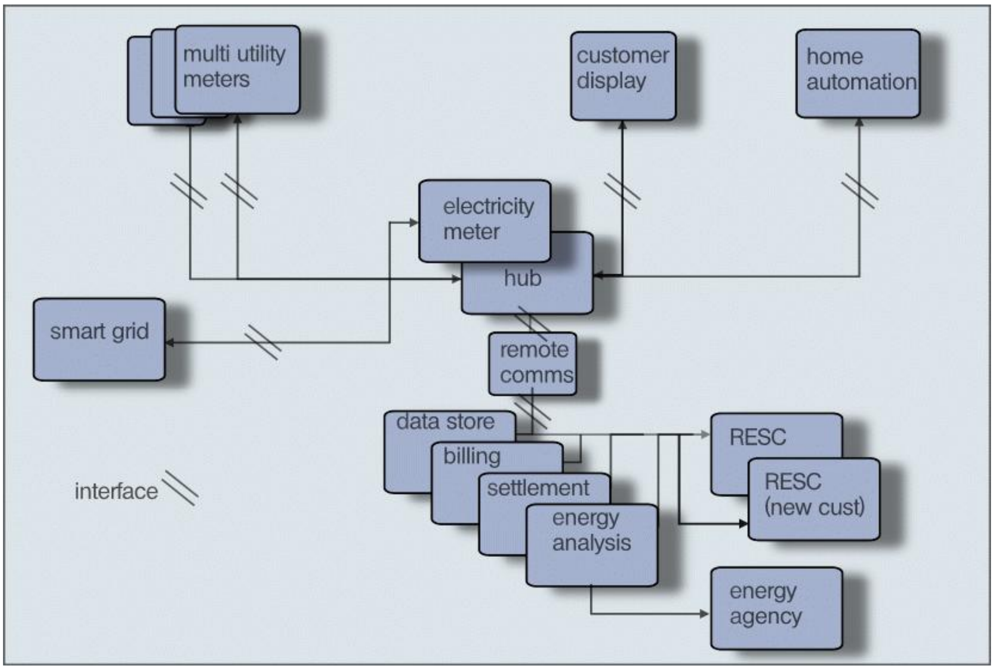

Figure 12.3 interfaces across smart metering network

The existence of all of these networks creates a dilemma for those implementing smart metering systems. Should they:

- ignore the possible links and concentrate only on the essential smart metering elements
- accept the need to link with the other networks and try to develop a comprehensive set of standards that includes all of the networks
- accept that they only have control of the smart metering element and simply define interfaces to the linking networks

The first option would limit the benefits that can be delivered by smart metering (some important to ESMA), the second would put smart metering in competition with those bodies already active in those areas, the final option is probably the preferred but it leaves many questions over which variations of the different networks smart metering should have interfaces defined.

Putting these concerns to one side, and having identified the wide range of interfaces and different types of networks involved in a comprehensive smart metering system, it is useful to list the relevant standards and the organizations active in the areas. Examples of the standards and protocols being developed in this area are shown in Table 12.1.

Table 12.1 Smart metering and related networks

Network	Organisation	Groups Active	Status
Smart grids	IEC	IEC TC57	Proposal to define standard for passing data from smart meters to network monitoring systems
Multi utility	ANSI C12 series DLMS/COSEM/OBIS M-BUS KNX ZigBee Z-Wave	ANSI DLMS User Group	Various systems that are incompatible. ANSI and DLMS are most comprehensive smart metering standards but may not cover all aspects and interfaces to other networks
Customer display	Zigbee Z-Wave Bluetooth low energy M-Bus radio Wavenis KNX OneNet	UK Energy Retail Association US OpenHan NL DK Electricity Savings Trust	
Home automation	HomePlug OneNet LonWorks X10 Zigbee Z-Wave	OpenHan TAHI CEDIA CENELEC DNLA	There are a large number of different and incompatible systems. These have been developed to use different communication mediums or for different applications.
Remote communications	ANSI C12.22 DLMS/COSEM/OBIS M-BUS		A number of end to end standards exist

12.5. Standardisation applied to smart metering

Thus far the implementation of smart metering has been done on a utility or national basis. For example, ENEL was a large, vertically integrated utility that implemented an AMR scheme across Italy. In Sweden, the government set a requirement for an accurate monthly meter read and, in response, Swedish utilities have been introducing smart metering schemes, each fully contained within its own commercial boundary. It can be expected that, as member states seek to respond to the requirements of the ESD, many future smart metering implementations will be driven at a national level.

These developments are not simple as, in most countries, a number of parties must agree a common approach, increasingly so as market liberalisation progresses. This means that competing utilities will have to find common approaches or risk implementing incompatible schemes with consequent high costs of final customer switching. Given the challenges of agreeing a national scheme there has been a tendency for them to be developed in isolation from initiatives in other member states and burden their developments with the additional difficulties of suiting the systems to multinational requirements.

However, in principle, smart metering is based on international components; meters, communications networks, business software and such. In theory, it should be possible to consider a universal approach to smart metering, applicable in all member states, albeit with an allowance for national requirements. This would have to be based on a standards approach. Indeed, the need to meet the requirements of the various Directives increasingly makes this a necessary development and attention has begun to focus on how it can be done. Such a common approach would have a number of benefits although not without some associated disadvantages:

Benefits of common standards approach to smart metering	Meter and associated equipment would be manufactured in larger volumes resulting in lower costs. Larger markets would also encourage more innovation from hardware and software developers. By avoiding the need for each member state and national metering stakeholder to investigate and develop their own approach, less regulatory, industry and government cost would be required. By repeating a common approach across Europe there would be a significant benefit arising from shared experience. This would result in lower risk associated with each implementation. Also this creates much enhanced opportunities to spread best practice. This would also be relevant to experience gained in securing energy savings. A common approach would also support European Commission objectives for free market in services. There is a danger that the development of incompatible national schemes will lock final customers into their existing energy retailer or restrict market access to local companies that have the necessary knowledge to operate the schemes. The costs for new entrant companies would also be lower if they could replicate a common approach in different countries. The cost of developing, marketing and implementing new services would be lower and the objectives of the Service Directive [SD 2006] will be compatible with a common approach.

Disadvantages

It is possible to develop bad standards that are overly complex or hard to apply. This topic is discussed by Tanenbaum [Tanenbaum, 2003] where he points out that standards should be developed after the initial technical development but before the widespread adoption of the technology. Catching the right moment is critical to developing good standards. Smart metering is in severe danger of leaving the development of standards too late and it is possible that there will be a wide scale roll out smart metering before the common standards have been introduced.

A common approach across Europe would require the agreement of a majority of Member States on any new standards. Given the need to account for local conditions in any such standard, the difficulty of reaching such agreement should not be underestimated. The time required to reach such agreement can be expected to result in delays compared to individual national implementations.

Once a common approach has been agreed it may be harder to introduce innovation, simply through the greater numbers of parties involved. There may be benefits to keeping certain elements of the system constant whilst allowing other elements to change and innovate. For instance, if all smart meters have a common data export port making available a defined data set, then many new and innovative devices could be developed to use these.

Compared to a number of national schemes a single international scheme will provide fewer opportunities to try different technical approaches and slow innovation. This disadvantage is probably small compared to the benefit of avoiding multiple incompatible implementations.
The variety of national conditions will result in making any common system larger as, for instance, it must include data entities as required for all member states and allow for all commercial models. It would be an option to have a ‘meta’ standard that includes all elements but, at a national level, only implement those elements required locally. This could have the effect, however, of reintroducing the local variations that the common approach is intended to avoid.

Appendix 3contains a review of standardisation issues for smart metering in general.

Major challenges for standardisation

Any exercise in developing a common approach will face many difficulties but there are a number that will cause especial difficulties:

A useful common approach would offer interoperability across many systems. Progress at national level shows that this is hard to achieve within the constrained borders of a single national scheme. This will be even more difficult at an international level.

There are a number of country specific market requirements. For instance the UK would require a scheme that accommodates pre-payment functionality, as it has 1.5m final customers supplied through these arrangements. The UK is the only European nation with such a high level of pre-payment final customers. Would all other member states wish to add considerable complexity (and potentially cost) to the common approach just to meet the needs of one member state? However, the UK is not alone in having a unique market mechanism, or indeed pre-payment. There is a variety of maximum demand arrangements across Europe that is unique to their own country. Any common approach would have to account for all of these. Against this, it can be said that, physically, the meters for all of these applications will be similar (metrology element, switch, display and communications. Any variations across borders would mostly be in software, not hardware,

As energy markets are increasingly unbundled in response to the European Commission objective of liberalising energy markets, there is an increasing separation of agents involved in metering. This has been taken furthest in the UK, where most aspects of metering have been separated. However, the UK is not alone in moving in this direction. Any common approach would have to meet the needs of the most unbundled market. This would result in many member states having unnecessarily complex systems. This may, though, be a useful feature as it would prepare all markets for unbundling, even if they have not yet reached that stage in the development of their markets. Again, there is a positive side to this; the European Commission is committed to liberalising energy markets. By adopting common standards that cater for the hardest cases - the most unbundled, it would prevent the smart metering system becoming a barrier to further liberalisation.

A fundamental stage in developing a common approach would be the agreement on a common system architecture. Whilst many different local arrangements can be accounted for within the detail of the common approach, it is not possible to bring together fundamentally different system architectures.

12.6. Customer feedback information

As has been shown, because they are not new, many aspects of smart metering are already covered by national and international standards. Other areas, such as Wide Area Networks and interoperability, are not fully covered but these do not directly affect final customer feedback and are not explored here beyond the need to ensure that the standards support the data entities needed to provide the necessary services and within the necessary time scales.

There is one key area, however, that is currently poorly served. This is the area of energy usage feedback and involves those parts of smart metering that stream information to final customers or their own or other agents' systems via a Local Area Network. This situation reflects the fact that this is the element of smart metering that is relatively new and unexplored.

This is a key area for future standards development. It would be unwise, at this early stage, to overly specify the provision of data to final customers as this would limit innovation in an under developed area. However, standardisation of elements of the system could be very desirable at an early stage to give developers confidence in the market for their products, based on these standards. For example, if the interfaces and the data entities available from meters plus their format and units were defined by Standards, then developers could produce innovative displays, software and devices based on these standards.

From a final customer feedback and energy saving point of view the key issues related to connecting to the meter include:

Common minimum functionality

Any development of interoperability in smart metering, energy efficiency improvement and final customer feedback will depend on meters having a minimum common functionality.

Interoperability

The aim of standardisation in general is to ensure interoperability within the scope of the standard. The key issues regarding interoperability for final customer information is that, where they so choose, energy retailers can adopt the installed smart meters when final customers switch to them. This would imply that energy retailers agree a minimum level of functionality related to final customer feedback that all energy retailers provide. It may be possible that energy retailers choose to avoid interoperability in some areas. For instance, different energy retailers could choose to supply different feedback displays. The display and its functionality would become a differentiation between energy retailer contracts. But even this approach though outside of interoperability, would depend on the different displays being able to access data from the meter LAN in an interoperable fashion.

Also standardised data items, format and units are necessary for interoperability. Data from meters of different manufacturers should be readable and correctly understood without conversions or proprietary knowledge.
Such a standard would require to specify the data that is available from the meter. Such standards currently exist (c.f. COSEM/OBIS) but lack some important data entities that would be needed for energy efficiency use.

Suggested additional data entities are[10]:

carbon associated with delivered energy stream	$kgCO_2/kWh$
average calorific value of natural gas supply	kJ/m^3 or kJ/kg

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[10] Where European regulations require utilities to supply this type of information to the customer with the annual energy bill then the smart metering system should use these types of data.

unpaid bill for energy stream / date of bill / value of meter reading at date of bill	local currency

It is interesting to note that, if the carbon content of the energy stream were to be supplied by the Supplier as a data item related to the actual value of the energy supply, it would allow customers to reduce their carbon footprint by switching to a ‘green’ Supplier who sourced their energy from lower carbon sources. This would give immediate benefit to an environmental benefit both to the Supplier and to the customer.

The supply of the calorific value of natural gas streams would be complicated as this value varies with time and location across a natural gas network. Indeed, a benefit of smart metering systems would be to allow this figure to be provided to customers in an accurate and timely fashion. General access to this figure would allow the ESD and the MID to be reconciled, as the ESD refers to the kWh value of natural gas supplies whilst the MID specifies that these are measured as m^3 or kg.

Communications protocol

There are a number of different physical communication media and associated protocols as dealt with in the Chapter 4 ”Smart metering systems - technical options”. It is possible that no single approach will meet all requirements, for instance, wireless based systems may fail to work in all circumstances where some houses present heavy screening to the signals. Thus it is likely that a number of different options will be required even within a single smart metering system. However, if support is going to be provided then, simply on practical grounds, it will be important to limit the number of options. Ideally, whatever options are adopted it will be important to use open standards so as to facilitate connection to the meter.

Access control, data security and robustness

The energy usage data of final customers can provide considerable information about the behaviour of the final customer. Customers are entitled to privacy so this information should be protected. However, the data is also useful to criminals who can determine the occupation pattern for the property. Thus protocols will be needed to ensure that data is only made available to approved devices. Utilities will also require that only the data that it wishes the final customer to access is made available by the meter. This topic must consider the requirements of Data Protection Directive [DPD, 1995], certainly care must be taken when releasing final customer data to third parties for wider analysis in which case the data certainly must

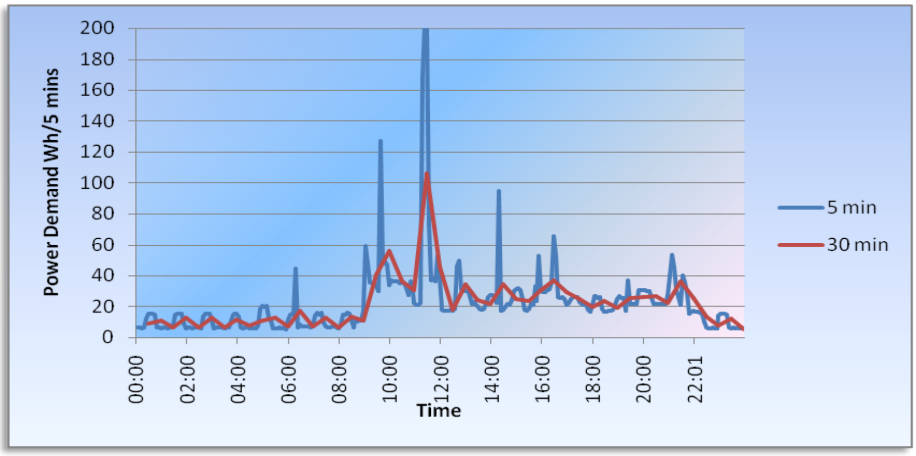

Figure 12-4 Daily electrical profile of a final customer

not reveal the identity of the final customer.

As an example this real life profile from a domestic final customer shows clearly that the house is occupied all day and that they go to bed at 22:30 and get up at 09:00. The graph also highlights the significance of shorter resolution data becoming available; the 5 minute resolution data shows that the final customer briefly got up at 06:30, detail that is lost from 30 minute resolution data.

The data will have to be secured, which will involve controlling connection requests to the meter and making sure that it only accepts connection requests from authorised devices. This will have to work reliably in the face of different possible system topologies, for example, the electricity meter might be used as a hub for other devices, such as gas and water meters and could be expected to communicate both its own data and that from connected devices. However, the electricity meter may alternatively be simply an input device connected to a separate hub device. Any standard must be able to accommodate this flexibility in system topology (or else all users must agree on a common system topology). The number of other devices connecting together must also be flexible; different properties will have possible connections between water, gas, heat, cooling and generation meters plus possible links to smart homes systems and or energy consumption software. Importantly for standards, some of these connections would be within the control of utilities and some would be outside of their direct control.

Extensibility

It is likely, especially given the early stage of development of this application, that the ways in which smart metering is utilised will develop over time, introducing new data items as yet not thought of. Given this possibility it would be wise to implement processes that feature a quality called “extensibility”. This feature is defined in Wikipedia as thus:

“In systems architecture, **extensibility** means the system is designed to include hooks and mechanisms for expanding or enhancing the system with new capabilities without having to make major changes to the system infrastructure. A good architecture provides the design principles to ensure this—a roadmap for that portion of the road yet to be built. Note that this usually means that capabilities and mechanisms must be built into the final delivery which will not be used in that delivery and, indeed, may never be used. These excess capabilities are *not frills,* but are necessary for maintainability and for avoiding early obsolescence.” [http://en.wikipedia.org/wiki/Extensibility].

Energy consumption analysis software

This term refers to the use of meter and other data to report to final customers on their energy usage. This area is outside of the meter field because it would deal with software and displays that have to draw data from a number of different sources (including meters) and combine these in useful ways. This will raise a number of issues, the chief of which will be the need for a common understanding of data meanings and units.

Smart homes

The data entities should include those required for smart homes application. These are described in Chapter 8 “Smart metering services for smart homes”. Smart homes devices should also be able to interface with the meter data via the LAN and access the available data. The use by smart metering systems of local area protocols that are accessible by smart homes networks will greatly facilitate this exchange.

12.7. Recommendations

- There should be an agreement on common minimum functionality and interoperability regarding provisioning of feedback from smart metering systems.
- European stakeholders should commence investigating the feasibility of adopting existing standards or developing new standards for use across Europe. These standards would need to cover physical and data layers and meet the needs of all European member states. As much as possible, the standards should allow freedom to innovate smart metering systems and feedback techniques.
- Data standards should be expandable to allow inclusion of entities such as those required to show environmental impact; such as carbon equivalent (for example, kg CO2/kWh) of the energy stream.
- Physical and data standards should be agreed for local communications with meters. These should enable non-utility devices and systems to access meter data. Standards should allow the control of what data can be made available by the meter and access to the data.

12.8. References

[CENELEC 2002] CENELEC, Uncovering the mysteries of standardization in Europe, Primer on Standards, 2002

[SD 2006] Directive 2006/123/EC of the European Parliament and of the Council of 12 December 2006 on services in the internal market

[CHESSS 2007] http://www.chesss.eu/mod_detail.cfm?moduleId=6

[PD, 2004] DIRECTIVE 2004/17/EC of the European Parliament and of the Council of 31 March 2004 coordinating the procurement procedures of entities operating in the water, energy, transport and postal services sectors

[DPD, 1995] Directive 95/46/EC of the European Parliament and of the Council of 24 October 1995 on the protection of individuals with regard to the processing of personal data and on the free movement of such data.

13. Marketing smart metering services

Smart metering may bring about substantial changes to the business model of energy retailers of small-scale final customers – both in terms of the type and also the scale of the services to be provided. However, achieving the expected benefits that are attributed to smart metering largely depend on its positive acceptance and correct understanding by final customers. This chapter examines the issues surrounding how smart metering should be presented to final customers.

13.1. Preparation for smart metering implementation

Smart metering can deliver a range of new services, such as improved consumption feedback as well as, for example, new types of tariffs (e.g. Time-of-Use tariffs, Block / Tiered tariffs, Critical Peak Pricing tariffs, Real-Time Pricing tariffs), related smart home, automated and demand-side control capabilities, and new services like smart grid functionalities and additionally safety measures [NCC 2008]. It is important to understand which of these services will be of value to final customers and their level of interest.

Any smart metering roll-out should be preceded by an in-depth analysis of the needs and perceptions of final customers which should help to define the type and extent of services to be provided by smart metering. This is especially important for mass-scale roll outs. This analysis should consider the initial and subsequent implementation phases and how different customer groups should be approached. This analysis will inform the services provided by smart metering but is also indispensable for determining the effective launch and marketing strategies that should be taken to ensure a successful roll-out, before, during, and after the installation of smart metering.

Identifying those services and information steams provided by smart metering that will be really demanded and valued by final customers has been the subject of several surveys and studies. One example of a recent study is [Energy Insights 2007] which was carried out in the US on the sample of 270 respondents, The study had the goal of verifying the interest of people in having real-time feedback on electric energy consumption and the type and extent of information that would be found valuable.

In the figures below, are reproduced some of the results. In Figure 13.1can be seen the percentage share of respondents’ answers (using a degree scale from 1 to 10) in reply to the question whether they would be interested in having a visual display unit (so-called “in-home display”) installed in their house. More than 2/3 (69 %) said yes. The answers of respondents on the question what type of information such a display (or smart metering generally) should provide is shown in Figure 13.2. Once again, a degree scale from 1 (no interest) to 10 (high interest) was used to differentiate the respondents’ preferences. Figure 13.3 then documents the willingness of respondents to participate in dynamic pricing programs if they will be equipped with an in-home display with which they would be able to control the operation of some (energy intensive) appliances.

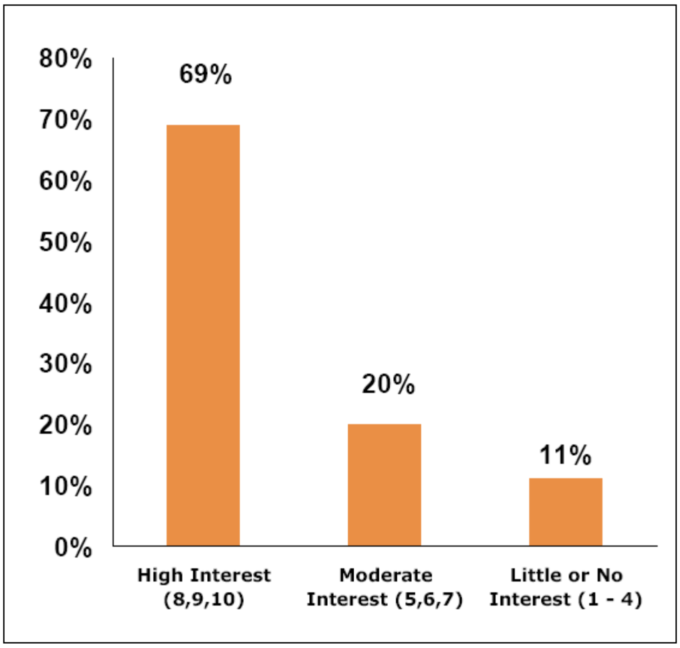

Figure 13.1 Customer Interest in In-Home Displays [Energy Insights 2007].

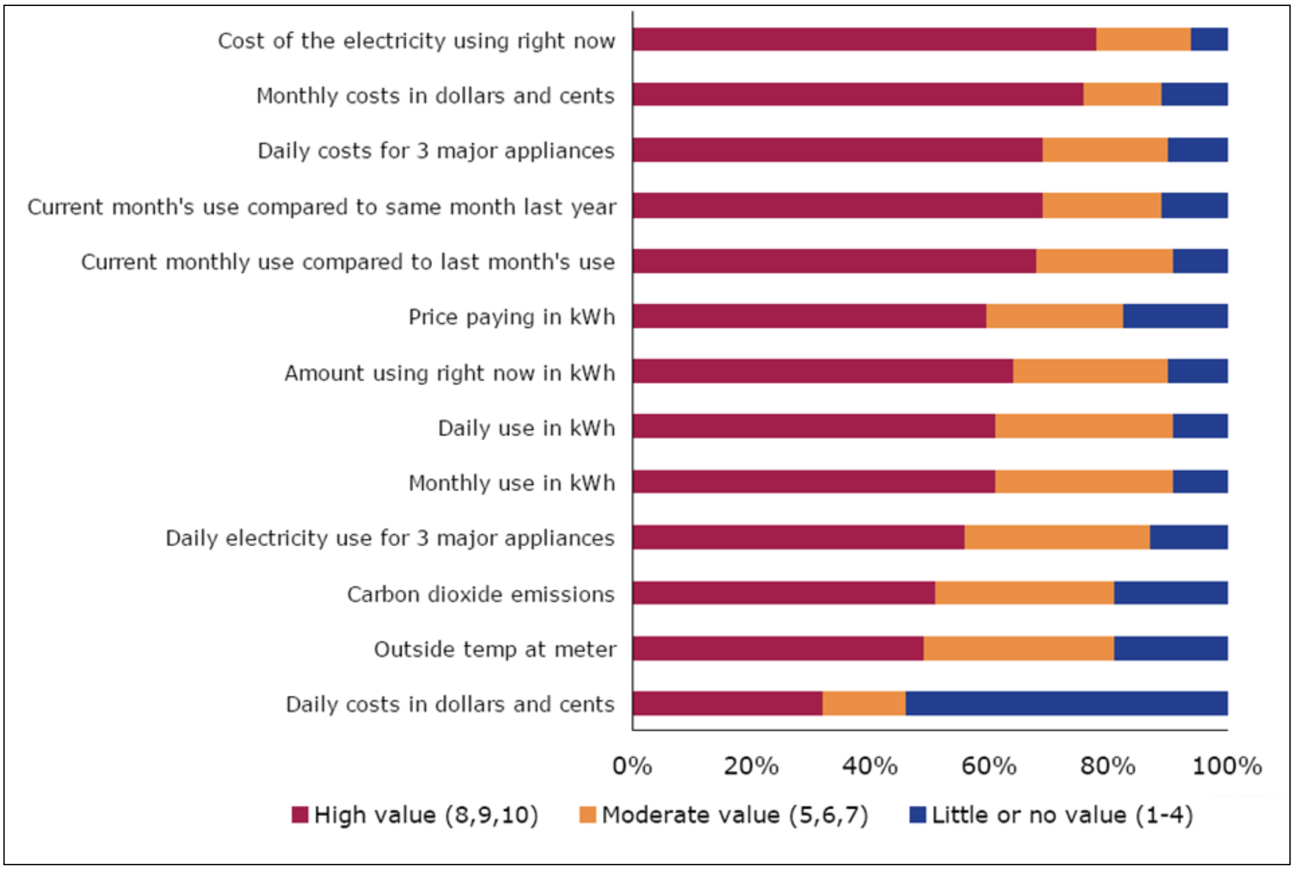

Figure 13.2 Information Customers Would Find Valuable [Energy Insights 2007]

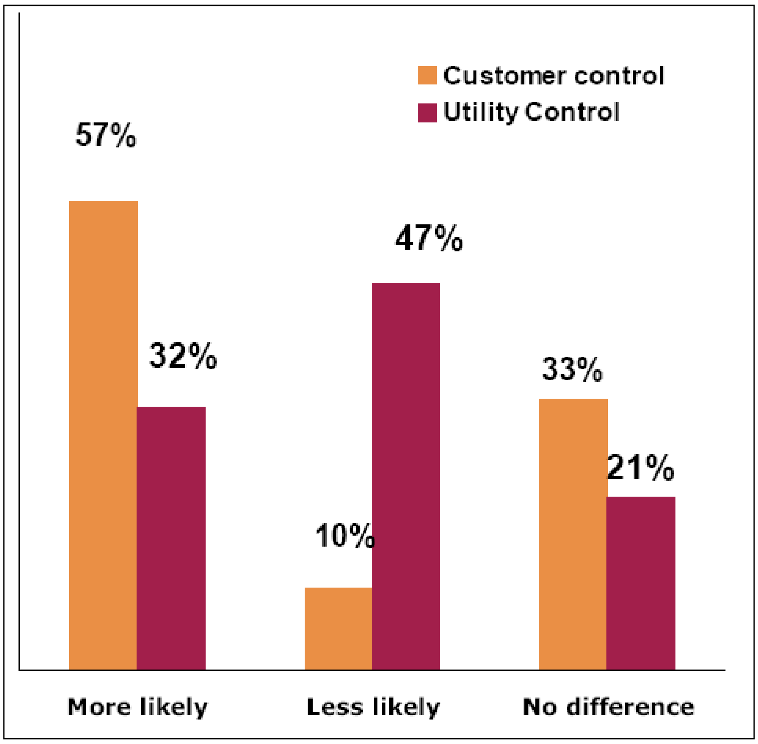

Figure 13.3 **Impact of In-Home Displays That Could Be Used to Automate Appliances on Dynamic Pricing Program Participation, Source: [Energy Insights 2007]**

Gathering such findings is very important for defining the specifications and functionalities smart metering should offer to the final customer.

Having identified the services that are valued by final customers the next step is to assess the probable impact such services/information will have on the behaviour of end customers (and what consequences it will bring for other market players). Again, this question has been the subject so far of extensive research and numerous trials (see Chapter 3 “Smart metering and customer feedback” and also Chapter 10 “Determining energy efficiency gain using field trials”).

An example of such a trial, which is the Energy Demand Reduction Project (presently underway in the UK) and which also is the largest and most extensive carried out so far worldwide.

Commissioned by the UK Government, the project goal is to verify how much customers will reduce their energy use or change their behaviour if they get better information from different types of feedback information instruments and routes. The trial involves a sample of 40,000 households in total.

The feedback information is being provided in various ways including visual display units, more informative energy bills, targeted energy advice and web and TV-based portals. The trial includes 47 trial groups and these are observed testing the effects of individual feedback methods and their combinations on defined several customer groups (e.g. vulnerable, high energy, random sample, communities etc.).

Although all the trials are scheduled to be completed by 2010 (to ensure operation through 2 winters) they already show some interesting information and experience [Ofgem 2008].

The trial had to face more technical delay then expected especially due to the longer lead time for smart meter orders. Furthermore, there have been a number of installation problems with visual display units (substantial part of VDUs could not be installed in the participating households for technical as well as “lack of interest” reasons, people stopped using them after the batteries ran out).

A customer survey research carried out as part of one of the trials observed a greater awareness of energy arising from the greater information provided on bills and energy efficiency advice given to participants. The first preliminary evidence on changes in energy use, if any, are expected to be reported by early 2009.

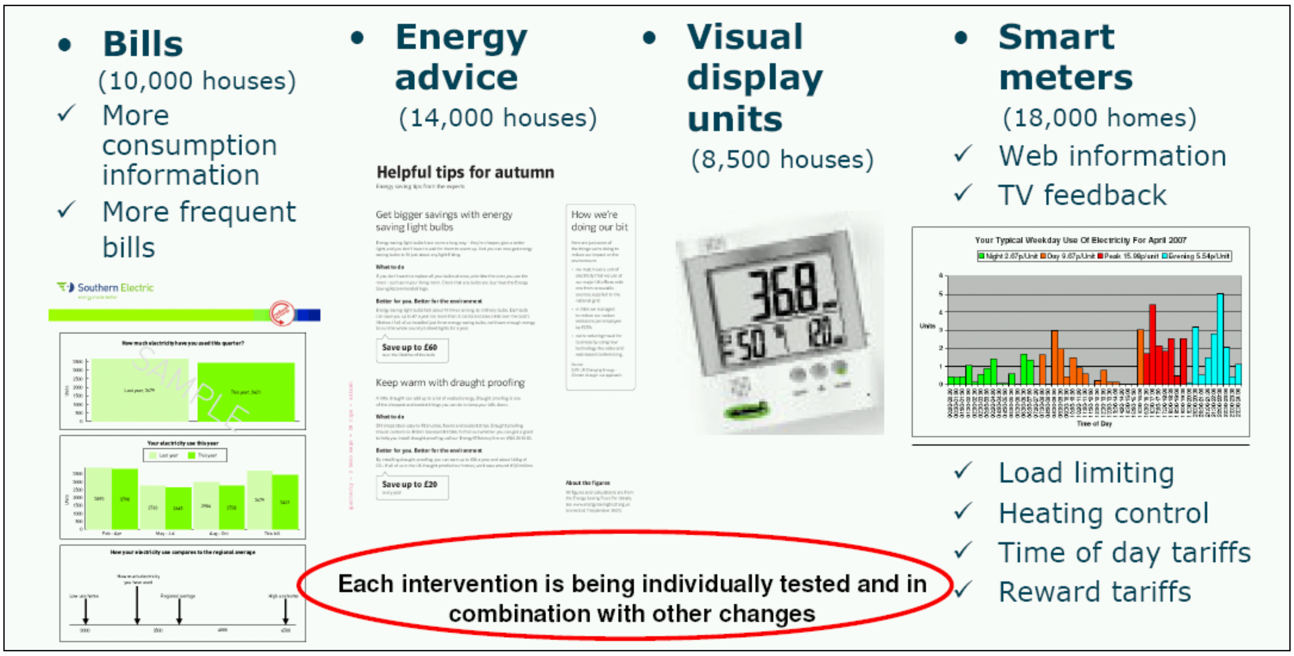

Figure 13.4 **Types of feedback instruments tested in the UK trial with the number of participants, Source: [Ofgem 2008]**

The ultimate goal of the trial is to identify the most proper type of feedback instrument(s) for a given customer group in order to maximize (societal) benefits in the form of reduced energy consumption and, consequently, carbon savings and to fix likely values on the benefits.

To summarize, market research surveys and pilot trials should be carried out to answer the questions; what type of information and services should be delivered by SM to a given customer type and how end users will utilize them. The final package offered to the customer should be produced as the outcome of well documented decision making process, carefully weighing the costs and benefits and thorough testing.

13.2. Marketing strategy for launch of smart metering

A critical aspect which will significantly influence the marketing strategy for launching smart metering services will be whether smart meters are being introduced based under free market conditions or based on an obligation laid upon the energy retailers by the State.

It the former is true then the introduction of accompanying smart metering services will probably be more selective and customer oriented. However, since the latter seems more common due to the substantial investments required and significant costs reduction of scale, then a more extensive and robust roll-out will be needed. The marketing strategy for launching smart metering services should therefore be adjusted to each market model accordingly. It should also build on the findings from the market research and pilot trials.

Given the range and variety of customer groups it is recommended that market smart metering services are customized, which means using different communication strategies towards different market segments or customer groups. The reason for this is that the perceptions and views (and prejudices) of final customers towards smart metering and accompanying services may vary differ largely among various customers. Some of the “voices” that can be heard:

- I cannot do very much about my energy bill, smart metering won’t help to reduce it
- I am already doing everything possible and cannot further decrease my consumption unless compromising my living standard
- It is too complicated, I do not understand energy issues
- This is just another way to make unjustified profit from me
- What will happen with data on my energy consumption, won’t it be misused?
- They are spying on me

These are just a few examples of negative expectations and grievances that might need to be dealt with in the marketing campaign.

In general consumers can be expected to want:

- Information about smart metering and its installation from trusted and independent sources including government, its agencies involved in energy conservation and consumer bodies
- To understand the reasons for switching to smart metering
- To understand any developments that may follow ,such as billing changes, improved consumption feedback and potentially new tariffs
- To understand the smart meter roll out program, how and where to apply for the smart meter I it is an optional choice and how the installation will proceed

As in any other public promotion activity it is important to clearly communicate benefits to the target group through appropriate channels using suitable communication modes.

To enhance the energy efficiency messages associated with the smart metering launch, the DSO or energy retailer might consider working with an independent third party body to explain to the final customer the benefits of Smart Metering. This could be a local or regional energy agency or consumer body that should act as a mediator and advisor providing unbiased information to final customers.

Smart metering services do not have to be introduced all at once and there may be merit in introducing the services step wise. This can allow final customers to deal with the changes in smaller steps. For example, smart meters could be installed first fitted with local network interfaces and simple in-house displays. Later the energy retailer could offer a more sophisticated display and analysis tools as a premium in service charged at a standard monthly fee. Such a step-wise approach may better assign costs towards those who will benefit most from (or value) smart metering features and functionalities.

A similar approach can be taken with the provision of advisory services that allow a final customer to identify (economic) energy savings measures. Again this could take the form of a limited universal service with the subsequent provision of a more complex service that could be offered by ESCOs or energy agencies, for example. In general these services might be offered by companies in charge of or obliged to secure “negawatts” based on the stipulations of the ESD but could also be open to companies on a straightforward commercial basis.

All of these factors must be considered and effectively communicated to targeted audiences if the success of the smart metering launch is to be ensured.

13.3. Installation roll-out & post-installation support

A smart metering roll out is a very complex undertaking and even though solid preparation has been made, surprises can never be completely ruled out. A mismanaged smart metering installation will carry major reputation risk for the DSO or energy retailer. It is therefore in their best interest to ensure customer convenience and responsiveness during the smart metering roll-out and installation.

Here, again, the crucial parameter will be whether smart metering will be introduced on a free competition basis or will be the result of a national or regional mass roll-out campaign.

DSO’s or energy retailers should do their best minimize the inconvenience for final customers arising from the meter installation. The installation can also be used to provide training to the customer provided that the installers have been appropriately trained. Certainly, the meter installers must be well briefed on how to answer customers’ questions, even if they are not intended to provide training.

In the post-installation period, the DSO or energy retailer should continue to provide essential support services to the customers while looking for options to expand their existing services as well as increase the efficiency and robustness of the system. This will require regular feedback from customers and their representatives.

13.4. Recommendations

A major plank of any successful roll-out will be that consumers understand and broadly accept the reasons for smart meter installation. It is therefore recommended that to the DSO or energy retailer:

- Involves the end customer and marketing departments as early as possible
- Begins with surveys and trials to identify the services that will be well received by final customers and effective in reducing energy consumption
- Designs the marketing plan for mass-scale smart metering introduction based on the results of the surveys and trials
- Minimises the inconvenience for final customers during the installation phase and especially make sure that there are sufficient properly trained staff to deal with customer queries and complaints arising from the installation of smart meters (this should include the installers)

13.5. References

[Energy Insights 2007] National Residential Online Panel In-Home Display Survey. Energy Insights. October, 2007.

[Ofgem 2008] Smart metering in Great Britain: Trials and Regulations. Louise van Rensburg, Senior Economist GB Markets, Ofgem. Metering Europe Conference, Amsterdam. September 2008.

[NCC 2008] The consumer implications of smart meters. National Consumer Council. July 2008.

Appendix 1. Smart metering design options

There are many options related to the communications between the meter and the data servers of the meter operator. This Appendix describes some of the main design choices, relating to:

1. Meter configuration options
2. Network topology
3. WAN options
4. Wireless Communication

This Appendix is intended to be informative for the reader new to the subject of smart metering and is not intended as an authoritative or complete description of the topic. Smart metering systems hardware comprise a number of different components and these are described below.

A1.1 Meter configuration options

There are a number of options for the provision of smart meters. These are described below.

Fully functional meters

The most common view of smart metering is that the meter itself has the functionality to make data available to local or remote communications channels. This option requires the supply and fitting of a purpose made meter as those meters that have been fitted in the past do not have this capability. This is clearly an expensive option, as all meters must be changed and the old meters must be scrapped, as they cannot be used in the new system (commonly referred to as “stranded”). A major advantage of this approach is that it makes available all the remote meter management features as these can be included in the new meter design. Also all the components of the system can be included in the meter where they are well protected and covered by the meter manufacturer’s quality control systems. This approach is normal where there is a significant increase in the functionality of the meters, such as where a switch or valve is included for electric and gas meters respectively. A disadvantage is that changing to a new communication network or adding some new functionality may require installing a new meter depending on the capabilities built into the meters.

Modular devices

Meters can be manufactured so that additional components can be added to the meters at a later date. Modules can be chosen based on the local needs and possibilities regarding communication, quantities to be measured and the type of final customer and location in the network. This is an attractive option where a smart metering system is being implemented. Where meters need to be fitted out of range the communications networks, a meter with an empty communications module can be fitted. When the meter is within the range of a suitable communications network the corresponding communications module can then be fitted. This approach also allows meters to be adapted to different communications networks and to be upgraded as the smart metering system evolves. Disadvantages of modular meters are that they are necessarily more expensive and less reliable because of the inclusion of physical connectors. Also, where meters are modified on site, it is less easy to provide the same level of quality control as when they are assembled in a manufacturing plant. Most importantly, probably, is the necessity to visit the site to make any changes as the cost of the visit is comparable to the meter cost, the savings from this approach are not as great as might be thought

Add-on devices

In recognition that final customers currently have meters and that costs can be reduced if these meters are re-used, a number of devices have been developed that allow the meter display to be read remotely. This can be done either by counting pulse outputs from the meter or by reading the meter's display using optical character recognition devices. This approach does not allow remote management of the meter as there is no connection to the meter. In the event that there is no intention to extend the meter functionality beyond that provided by the existing meter, then this approach can have merit. For instance, where a dual fuel system is being developed, often there is no intention to add functionality to the gas meter. In this case a battery powered pulse or optical reader can provide access to the gas meter reading and, using a wireless link, pass this data to an electricity meter acting as a hub.

Add-on devices face a number of issues: they can be dislodged from the meter by the final customer. There is also no direct access to the meter data, rather the reading depends on the reliability of the pulse counter (often suspect with utilities as it cannot recover from missed pulses) and optical character readers (which are new and suspect until proven through widespread use). Maintenance and upgrading can be difficult and prone to scaling errors, because it may be difficult to change and check the scaling of the pulses.

Flag devices

An alternative to pulse readers or OCR devices are devices that connect to communication ports that are already provided on many electronic meters. These have the same advantages as the add-on devices but also provide access to meter functionality and also access the internal meter data, avoiding any concerns over accuracy or reliability. The device can also be fitted independently from the utility supplier, although with limited access to the meter functionality.

These devices make use of the FLAG port, included on many digital meters. The FLAG port gives full access (with appropriate security) to all the features and functions in the meter. Many mechanical meters are now being replaced with digital meters which include a FLAG port. In the UK over 20% of meters are now digital, in some areas as high as 50% and this is increasing by about 5% per year.

The use of such devices can be beneficial during the role out of smart metering as it can avoid the need to replace all meters before achieving a high degree of remote meter reading. This would give the utilities the option to bring more meters into the new billing system without replacing all the meters. A disadvantage of this is that, firstly, site visits may still be necessary, and this is a major part of the meter replacement cost and secondly, the cost of the Flag port readers must be added to the cost of the replacement meters, increasing the total cost of implementation, although possibly spreading it over a longer period.

Independent devices

Electricity consumption data can be acquired completely separately from the metering system. A number of systems have been placed on the market that use a split current transformer placed around the incoming live power cable. This can be used to measure the current and, by assuming the supply voltage, calculate and display the power consumption. These systems have suspect accuracy as they use an assumed voltage and cannot determine power factor. However, they can provide an indication of power consumption and this is of use to some final customers. Most crucially, though, they do not provide any communications channels with the energy retailers and so fall outside the scope of ESMA.

A1.2 Network topology

There are a number of ways in which components in a network can be connected with each other and this results in design choices that are relevant to smart meter communications. This review assumes wireless communications although there are similar topologies for wired networks. WAN communication often has two levels: 1) between the meter to the concentrator and 2) between the concentrator and the head end system with the metering value data base. Also single level systems without any intermediate concentrators are possible. Topologies and technologies for both levels can be individually chosen.

Peer to peer

This is the topology used in Bluetooth networks, for example. Each component has a direct link to the component it is communicating with. These links are all one to one. This provides for simple networks with little flexibility where each communication node has to have the same functionality.

Star / Concentrator

In this arrangement, the meters within a single group are all connected to a single concentrator node. This may be a special meter or a separate communications node linking the meters to the WAN system. This network arrangement offers good economy and battery life, because the individual meters only need sufficient power to contact the base station and external communications are channelled through a single link. The disadvantages are that the size of the network is limited by the range of the communications link between the individual meter and the base station. Also, the local terrain can create radio black spots where meters cannot be connect to the base station.

Mesh

A relatively new topology, mesh networks support communications between all meters as well as with the concentrator. The network mapping is designed to establish itself automatically. When first turned on, the meters broadcast and respond to the other meters in their area. In this way the meters establish which meters they can communicate with and work out paths to transmit and receive data from the concentrator. The network can extend well beyond the range of individual meters because intermediate meters can act as relay stations. The network can also cope better with black spots because local meters can provide paths around obstructions. The limits of such mesh networks are related to the number of steps that can be tolerated before communications become too slow.

These design concepts lie behind the following description of communications options.

A1.3 WAN options

The main options for communicating from the central base station to a node in the house fall into the following categories.

Leased line

A leased line is a dedicated telephone line used to link two locations. This is a very reliable system but is correspondingly very expensive. For data transfer a modem is required at each end of the connection. A leased line provides far more bandwidth than would be required of a domestic meter. Leased lines are rarely used for metering applications but are used for meters monitoring major energy flows, such as power stations.

PSTN

This is a similar arrangement to the leased line except that the public telephone system is used to connect to the meter. Again a modem is required at both ends. For domestic applications it is likely that the phone line will be shared with the final customer and it is important to prevent data calls causing their phones to ring. There are a number of techniques that can be used to achieve this. One that works with the UK telephone system is Caller Line Identification (CLI). The principle of this is that all phone calls are preceded by a data string that identifies the caller’s phone number. The CLI modem interrogates this string and, if it matches any numbers in its memory, it picks up the call before the phones ring. The modem is designed to drop the line if the final customer tries to make a call so that it never blocks emergency calls. A draw back with CLI is that, if the modem fails, it does not pick up the line and the telephone rings, causing considerable final customer nuisance. This is compounded by the fact that calls are often made during the night to avoid contention with the final customer’s use of the phone. Another drawback is that the connection depends on the PSTN contract of the final customer. It has happened that the access to the meter has been lost when the final customer has stopped his PSTN contract either due to replacing it with a cell phone or due to moving to a new home. Although such situations are rare dealing with them can cause significant costs. A third drawback is that it is not suitable for services that require multicasting or sending of alarms.

Wireless

There are a number of different ways in which wireless communications can be established within a house

- GSM

This is the basis of the current mobile phone system. It can be used in a very similar way to the PSTN by the use of modems to enable data communications. Calls can be of arbitrary length but their cost increases with their length as does the risk of a communications failure during the call.

Alternatively, the mobile phone network can be used to send SMS text messages. These require much less bandwidth and are a form of packet communication so there is no need to establish an end to end link. SMS messages also require less power to transmit and are often used with battery systems. The disadvantage of SMS communications is the limit on data length (160 characters).

Longer messages can be sent in multiple SMS messages but, where the objective is to limit battery usage, this can be unacceptable.

A significant difficulty with GSM communications is that network coverage of given areas cannot be guaranteed. Although national coverage is very good, there are always areas where reception is poor locally because of hills and other obstructions or because the network does not cover it. United Kingdom meter operators typically expect some 5% - 10% of sites to be beyond the reach of a given network. One option is to make use of the fact that the different networks have different coverage patterns. Thus, by using a different SIM card, it can be possible to access a site that can't be covered by an alternative network. The challenge here is commercial, as, traditionally, cross network charges are very high. Data collectors can manage this by having multiple contracts with the different GSM service providers. Ultimately, it might be possible to get SIM cards with roaming capability, so that they simply pick up the network with the strongest signal. This is well beyond the current commercial thoughts of the network operators.

Costs of GSM communication are very hard to predict as different network operators can offer deals structured in different ways.

GPRS	General Packet Radio Service (GPRS) is a mobile data service available to users of GSM mobile phones. It is often described as "2.5G", that is, a technology between the second and third (3G) generations of mobile telephony. It provides moderate speed data transfer. Generally, the connection speed drops logarithmically with distance from the base station. This is not an issue in heavily populated areas with high cell density, but may become an issue in sparsely populated/rural areas.
3G	3G offers more bandwidth than GPRS but also consumes more power than. Thus during power outages wide band wireless communication network will stop almost immediately in order to save batteries. For many possible smart metering based services 3G or more generally wide band wireless technologies bring more imitations than benefits.
WiMax	Still being developed, WiMax is a version of the IEEE... standards that is viewed as a fixed wireless alternative to PSTN or cable broadband networks. It requires a combination of protocols to give long and short range communications. Central stations can reach up to 15 miles with line of sight contact. To provide economic network coverage, WiMax is competing to gain access to the low frequency wave bands that operate over a long range. WiMax operators are gaining access to the frequencies being given up by analogue television and their entry to the market has been held back by the wait for this to begin. In the UK a WiMax network is being installed in Manchester [Ref] and this is viewed by some parties as a real option for smart metering applications.
Low Power Radio	Low-power radio is the concept of broadcasting at very low power and low cost, to a small community area. Low power radio products offer rapid implementation of high-reliability, cable-free data links. Transmitter power output is fully programmable up to a maximum of 10mW, allowing the modules to be used within any of the

	lower-power sub-bands within the overall 868-870MHz band. A line-of-site range of 250m is easily attainable. A recent implementation in Gothenburg has used the ZigBee system to set up a low power mesh network for smart metering.
WiFi	This is the same as the WIFI used within properties. There is a trial of this system being carried out in Burbank, California, US. A number of cities have been experimenting with establishing city wide WiFi networks to allow people to connect to the internet as they roam around the city. Where such networks have been established they can be used for smart metering.
Power Line Carrier (PLC)	Given that the meter is connected to a wire network, many groups have had the idea of using the power network for carrying communications and a number of different standards have been developed. Put simply, a data concentrator is connected to the low voltage (LV) network (typically at the transformer) and this imposes a modulated signal onto the fundamental 50Hz mains signal. Communications modules are fitted to all the meters on the network and these detect the message or send messages to the concentrator. The network can send and receive data from any individual house connected to it. This has been used in Italy for the ENEL smart metering system. There are a number of competing standards, which has caused some delay in the adoption of PLC. Many PLC technologies used for smart metering suffer from so narrow bandwidth that it limits the future possibilities to develop the functionalities of smart metering and bundled services unless means are found to increase the bandwidth.
ADSL / Broadband	Broadband connections are growing at a very high rate, with over 42% of European homes now connected in 2007 (Eurostat), predominantly provided as an ADSL connection through the existing telephone line. Although they share the line with the voice service, they operate at different frequencies so that the broadband link can be used at the same time as the voice link. Broadband connections provide far higher data rates than likely to be needed by smart metering. The main drawback to their use is that they are not under the control of the energy retailer or DSO, nor can their availability at any site be guaranteed. Lack of multicasting, periods of interrupted service due to maintenance etc. and lack of traffic prioritising also set some limits to what kind of services can be based on normal low cost ADSL services of the telecom operators.

Any local network will comprise a link to the WAN and a concentrator to link local devices. It is likely that these may be combined in the electricity meter (with the advantage of a ready electricity supply) but the concentrator can be outside the electricity meter. Whatever the topology, some of the options for connecting the elements are set out below.

A1.4 Wireless communication

WiFi

This is an industry standard wireless protocol that is increasingly used to connect electronic equipment around the home and office. It is feasible that this link could be used to connect the meter into the home network and thence to the internet via TCP/IP protocols. It has a very high bandwidth and is suitable for streaming multi media around the home. This makes it expensive and power hungry for the needs of normal meter communications.

Bluetooth

Bluetooth was introduced as a wireless link to replace the many cables used to link computer equipment, such as the pc and the printer. It has a shorter range than WiFi but could be used to link meters to a household LAN. As with WiFi, it has a higher bandwidth than might be needed for meter communications with corresponding issues of cost and power consumption.

Zigbee

Zigbee is a relatively new protocol that is being adopted within the Smart Homes and commercial/industrial sectors. It has a lower data rate than WiFi and Bluetooth and uses a mesh network to provide a range of coverage. It can cope with 64,000 nodes, making it ideal for use in offices, and other large buildings. The protocol is simpler that either WiFi or Bluetooth meaning that is cheaper, requires less powerful processors and less power. It is expected to be available in meters soon and a new profile is being introduced to offer smart metering functions.

Zigbee is well suited to multi utility metering as the power demands are low. Thus, the gas and water meters can be linked to the electricity meter that, in turn, can provide the power hungry link to the WAN.

Z-Wave

Z-Wave has been developed from a commercial communications protocol. It sits below Zigbee with slower data rates and fewer nodes. However, its proponents argue that it is better suited than Zigbee for the domestic market where fewer nodes are required and its lower cost should give it an advantage. Z-Wave chips are expected to cost a few dollars each and its advocates believe that it will become ubiquitous in the domestic sector, allowing economic control of all aspects of the house.

Z-Wave would be even better suited to the multi utility applications as it shares the same advantages as Zigbee along with even lower power demand. It is claimed that two AAA batteries could provide a 10 year life.

Proprietary systems

Where the electricity meter is part of a unified communications system provided by a single equipment supplier there is no need for open standards to be used. In this case a proprietary communications protocol can be used, based on one of the unlicensed wireless frequency ranges. Such systems can be more reliable as the entire system can be tested by the manufacturer. However, it leaves the owner committed to the vendor’s equipment and support.

Wired system

There are two main options for wired systems, either PLC or twisted pair. If the electricity meter is communicating with other devices that have a mains supply it is then relatively simple to provide a communications link between them by fitting PLC transponders into their power supplies. The cost of the chips to enable this is little more than a few euros at each end. Meters are already available with in-built PLC and there are a number of systems available which already use PLC communications within the house to send data between different devices.

Twisted pair data links have been used extensively by utilities using the M-Bus protocol. They have not proven popular with other utilities because of the need to run cables around the property. There is a general trend away from such practice with such things as room thermostats increasingly moving to wireless links. However, the growth of smart homes infrastructures may result in houses having data cables or data cable trunking installed in the house. These may be accessible by the smart metering system.

Summary

The technical options for smart metering are an area where there is rapid technical progress so that it can be expected that new options will become available. Also, as more smart metering systems are implemented it can be expected that the market will increasingly narrow the range of choices. Future editions of the Application Guide will be updated to reflect these developments.

Appendix 2. Standardisation process

Standards and their purpose

Common Standards have been recognised by the European Commission as an effective means for opening markets in line with the Commission single market objectives. As such, standards have come under more legislative control in Europe than in other parts of the world. The Commission has used standards to support the New Approach Directives and has also sought to ensure that national standards do not conflict with European Standards. As a result there are several levels of Standards.

Standards are simply documents describing a common approach to a particular objective, developed through consensus amongst experts through an open manner under the governance of a recognised body. Their use is voluntary but their benefits make them all pervasive. There are many standards bodies around the world that focus on particular technical or geographical scopes.

Part 3 of the CEN/CENELEC Internal Regulations defines a Standard as “a document, established by consensus and approved by a recognized body that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context. Standards should be based on consolidated results of science, technology and experience, and aimed at the promotion of optimum community benefits “ [CENELEC 2002].

For the purposes of smart metering, standards promise to allow products from many vendors to be assembled into complex systems that can be relied upon to work reliably.

National standards

All European Member States have a National Standards Body that issues and maintains National Standards that are applicable in that Member State. These can be developed by that National Body for use only in the Country. However, there are rules that limit the freedom of National Committees to do so. Specifically, if a European standard is published, then all national committees must withdraw any national standards that conflict with it and they must publish the European Standard as a national standard. They are permitted to add no more than a cover page to the international standard text.

European international standards

CENELEC (for electro-technical standards), the European Telecommunications Standards Institute (ETSI), and CEN for all other standards, are the European bodies that have authority over European standards. For electro-technical standards, according to the Vilamoura procedure, a national committee must advise CENELEC if they either propose the development of a new standard or revision of an existing national standard. CENELEC will then advise other national committees of the proposed development and, if there is sufficient interest from other national committees, then an international working group will be set up to develop the Standard.

According to the Vienna Agreement, CEN and CENELC are also required to advise the ISO and IEC respectively, when they begin the development of a new standard. ISO or IEC can then bring the development of the standard under its own processes. In this case the standard would be published by the ISO or IEC, and adopted in turn by CENELEC or CEN and then National Committees. Under the Vienna Agreement, CEN and CENELEC have the authority to refuse to accept the involvement of ISO or IEC if they believe that this will unduly delay the development of the standard.

Harmonised standards

New Approach Directives, such as the Measuring Instruments Directive [MID 2004], set the minimum essential requirements for products within their scope. It is left to manufacturers to decide how to demonstrate that their products meet the essential requirements. However, it is common for CEN or CENELEC to be mandated by the Commission to produce Harmonised Standards that can be used to demonstrate compliance. These standards become harmonised when they are published in the Official Journal of the Commission.

Other international standards

The ISO (mapped to CEN) and IEC (mapped to CENELEC) are the world level standards bodies. Standards can be adopted by IEC or ISO, or vice versa. European National Bodies are free to adopt international standards as long as they are not in conflict with European standards. Other standards bodies around the world issue standards in their own name and these can be used by manufacturers and others if they better meet their needs. In the case of smart metering, ANSI in the US has its own relevant standards: **ANSI C12.19** UTILITY INDUSTRY END DEVICE DATA TABLES.

Other forms of industry agreement

The following text is taken from the CENELEC website (http://www.cenelec.eu) and describes a new concept that they have introduced to fill a gap where industry wishes to define ways of working together but is not in a position to develop formal Standards. Agreements can be developed more quickly using this approach than formal Standards and may be an appropriate route for the smart metering industry to take at this stage in the development of smart metering.

*“*The CENELEC Workshop concept is to extend the classical possibilities of standardization work by a new, flexible form aligned to market needs. As a consequence of open meetings, the current topics can be discussed within a broad circle of participants made up of manufacturers, service providers, users and consumers and in working groups or project groups. Results such as the CWA (CENELEC Workshop Agreement) may be determined.

CENELEC has created the **CENELEC Workshop Agreement (CWA)** as a deliverable which aims to bridge the gap between the activities of consortia and the formal process of standardization represented by CENELEC and its national members. The CWA offers a fast and flexible way to develop a standard. Consequently, it has also some limitations, for example “standstill” is not available. When needed, the CWA can be followed by a second phase conducting to an “EN” that provides the standstill feature. “

Appendix 3. Options for standardisation

Whilst any common approach would face significant challenges, it is probable that, with sufficient determination and resources, this could be developed.

Assuming that there was an agreement to develop a common approach, it would be possible to take quite distinct approaches to developing standards for smart metering. These range from very proscriptive specifications that govern the internal elements of the meters and leave little option for interpretation through to open systems that merely specify the interfaces between the different elements. The advantage of the tightly specified approach is that it gives good control of the system but at the cost of scope for innovation. The open system provides more scope for innovation and improvement, potentially beyond the expectation of its originators but at the risk of incompatibility. Standardisation for smart metering will require the identification of a very carefully chosen path between these two extremes.

There are currently a number of options which are considered in more detail:

Develop existing standards

There are standards that currently address smart metering, for example the DLMS series of standards [http://dlms.com]. It is generally agreed that current standards have been influenced strongly by the needs of the I&C markets where they are currently used. Any such standards would need further development to be applicable to European residential markets and the requirements of the Energy Services Directive [ESD 2006].

As well as the specific ‘smart metering’ elements, many parts of the whole smart metering system can be based on open standards; for example both local and remote communications can be based on ‘industry’ communications protocols, thus avoiding the need to invent new approaches.

Use the national approaches

There are a number of different national developments underway across Europe such as the Netherlands NES, the United Kingdom SMOF and Spain plus existing schemes in Sweden and Italy. This creates the opportunity for countries implementing smart metering later to examine these different approaches and either pick one for common use around Europe or combine the good features of some of the schemes. Such an approach would probably result in a standards approach based on the chosen schemes.

Integrated systems

There are a number of software vendors who market applications that address the needs of interoperability. They achieve this by placing a consistent application layer over a layer that caters for the different meter protocols. By building a library of drivers for the different meters catered for, the software can automatically manage communications with the meter and shield the user from that complexity. Examples are EIServer (based on MV90), EnergyICT, and Netinium.

Such systems are attractive as they avoid the need to introduce strict standardisation at the meter level. However, a drawback of such approaches is that the complexity of including disparate meter systems leads to a focus on common elements of the meters; those functions that they all share. This creates a barrier to innovation, as any new meter feature would need to be enabled within the software environment, a change outside the control of the meter vendor. This approach can be expected to result in steady progress towards a standards based system. There is also a danger that utilities would be swapping meter vendor lock-in for software vendor lock-in. Open software systems would avoid this drawback.

Meter implementation options

The previous text in this Chapter has reviewed the topic of standards and smart metering. It can be seen that this is a complex and incomplete subject where much future development can be expected. So what is one to do if faced with the challenge of implementing a smart metering system?

Those implementing smart metering systems have two clear options, neither of which appears to be ideal; wait for standards to be developed or press ahead in their absence. Waiting will be a safe option but could impose a substantial delay on any implementation. Pressing on now faces the risks that subsequent developments in standards will leave the system obsolete.

However, the latter risk should not be overplayed. Any new system should be designed on the basis of a 15-20 year asset life. So long as it is well specified and designed and meets the objectives of the organisation installing it, then it can have its own, independent existence, unaffected by subsequent changes in standards. The question then becomes how might changes in standards affect a system already installed that does not comply? This would qualify as a project risk and will require mitigating measures.

The major risk will be lack of support for any legacy systems installed and subsequently made obsolete by new standards. In actual fact the risk of non-standard systems becoming obsolete will exist even without the introduction of new standards. This risk can be mitigated if the number of meters in a given system is large enough to create its own market. It will be smaller implementations that face the greatest risk of losing support.

Even if implementing a non-standard system it is advised that the guidance provided in this document is followed, although it is hoped that this will be adopted by any new standards. It is important to require that the interfaces and their protocols and their documentation are freely available for all upgrading purposes that will emerge during the lifetime of the system.

From a wider perspective it is clear that there are major benefits that would follow from the development of European standards for smart metering. Costs of introducing smart metering could be reduced, risks reduced and opportunities for sharing best practice maximised. A standards based approach would also support the development of open markets. Developing a full list of data entities within smart metering systems that include items of importance for energy management would be a priority.

One area that should be addressed in particular is related to the provision of energy usage data to the final customer. This is a new functionality created by smart metering and represents an interface between the utility and final customer. As this should connect to systems outside the control of the utility it is vital that this link should be included in standards so that a market can be developed for devices that take this data and convert it into forms that are convenient to the final customer. This must be done whilst retaining control over access to the data.