CENTRE ON REGULATION IN EUROPE

Regulating Smart Metering in Europe: Technological, Economic and Legal Challenges

Report of a CERRE project

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This study has received the financial support of a number of CERRE members. It has been completed under the supervision of Professor Martin Peitz, Joint Academic Director of CERRE and Professor at Mannheim University. As provided for in the association's by-laws, it has, however, been prepared in complete academic independence. The contents and opinions expressed reflect only the author's views and in no way bind the sponsors or any other members of CERRE (www.cerre.eu).

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Executive summary

Large-scale deployment of smart metering technologies in network industries – currently discussed or implemented in many European countries – raises a number of major technical, regulatory and organisational issues.

This report identifies and discusses the main options available to the European governments, regulators and businesses.

Smart metering in energy and water industries

In comparison with traditional meters, smart metering introduces a number of new features. First, meter reading automation reduces the cost of incremental readings, to the point that the need for estimated billing becomes unnecessary. Second, smart meters collect high-frequency consumption data. This is a prerequisite for implementation of cost reflective energy prices, varying depending on the time of consumption. Third, smart meters may be designed to implement remote activation/deactivation of supply, set withdrawal ceilings and remotely control consumers' electric appliances or distributed generators.

These features are expected to yield benefits in retail service quality and cost, demand response to prices, energy and water conservation, distribution service performance and cost, electricity system operations and industry processes. Benefits can be expected to vary across industry sectors, with greater benefits to accrue first to electricity, then to gas and, to a lesser extent, to water.

In order to assess whether smart metering benefits exceed costs Member States have conducted cost-benefit analyses, as prescribed by EU law.[1] A survey of these analyses completed in this report shows that smart metering deployment plans considered in different Member States vary greatly, in terms of sectors in which smart metering is implemented, system architecture selected and scope of the plan.[2] Those analyses reach also different conclusions, with some Member States, such as GB,

[1] These analyses concern the energy sector. There is no comparable work for the water industry. However, in a multi-utility setting, the benefit of water smart metering might outweigh the incremental cost of implementing it, and therefore contribute net positive surplus to the overall cost-benefit assessment.

[2] Germany, for example, considers a plan in which about 20 out of 33 million installations will not feature basic smart meter functionalities such as remote reading.

France and the Netherlands, finding a positive social net value, while others, including among others Germany and Belgium, reaching the opposite conclusion at least for some scenarios and groups of consumers.

Further, in all cost-benefit analyses with the exception of France, energy savings are crucial for smart metering projects to have positive net value. However, counterfactual scenarios considered do not appear to contemplate alternative, and possibly cheaper, measures to induce changes in consumption behaviour. Further, additional costs for intelligent appliances – which are necessary to automate demand response to prices – are not accounted for.

Finally, in all European countries examined, with the exception of the Netherlands, installation of smart meters is or will be mandatory. Mandatory installation implies the obligation for one or more firms to supply meters. This is usually coupled with the obligation on consumers to make use of smart meters for at least a minimal set of functions such as remote reading – and to pay for them, in one way or another.

With mandatory installation, public authorities are making a determination that competitive market forces on their own do not suffice to bring about the "desirable" level of smart meter penetration. Indeed, the experience with unregulated markets in Great Britain and Germany shows a limited rate of spontaneous adoption of smart meters. Member States have been conducting cost-benefit analyses bringing into the equation the benefits from smart meter roll-out that would not have been internalised by customers on unregulated markets. In the cost-benefit analyses surveyed for this report, the benefits tend, however, to be mostly of the kind which should already have internalised by customers.

The arguments in favour of mandatory roll-out featured in the policy debate, including the national cost-benefit analyses, are not as clear-cut as one would expect in the case of such an important policy decision which involves material costs for consumers.

Scenarios for smart metering organisation

The analysis of smart metering technology in this report leads to identifying two broad groups of activities, potentially differing in terms of organisational regime. The first set, referred to as “meter availability” services, broadly consists in making the meter’s functionality available to the party in charge of collecting data. The second set of metering services, called “data management”, consists in ensuring that entitled parties have access to the right data, in the correct format and at the right time. The boundaries between the two groups vary according to the technological architecture.

Alternative scenarios have been investigated from economic and legal perspectives. They differ in terms of organisation of meter availability and data management activities. The economic analysis focuses on the relative merits of a liberalised and a monopoly organisation. The legal analysis focuses on the application of general EU law (internal market, EU competition law, including Article 106 TFEU) and of sector-specific energy and electronic communications regulation. It explores how EU law can both constrain the freedom of Member States in regulatory design as well as the behaviour of market actors. The scenarios developed in the report have also been compared with those analysed by the European Commission’s Smart Grids Task Force.

The following scenarios have been considered.

	METER AVAILABILITY	**DATA MANAGEMENT**
Scenario 1	Competition	Competition
Scenario 2	Regulated monopoly	Competition
Scenario 3	Regulated monopoly	Regulated monopoly awarded via tender
Scenario 4	Competition	Regulated monopoly awarded via tender
Scenario 5	Regulated monopoly	Regulated monopoly (not tendered)

Economic assessment

The relative merits of liberalisation and monopoly in metering services have been investigated from different perspectives. These include service range, innovation, cost, market power and the impact of smart metering on industry processes in the energy and water industry.

As far as meter availability is concerned, the main results of the report's analysis can be summarised as follows:

a) Innovation: since much of the design and technology of meter availability services needs to be standardised, the ability of competing providers to differentiate their offerings appears limited. However, a liberalised setting for meter availability would make it possible to exploit synergies and scope economies with other services that might be lost in a monopoly model.
b) Cost of service: since a large share of meter availability costs is (or can be efficiently placed) outside the regulated firm's control, the advantage of liberalised models relative to regulated monopoly in inducing cost minimisation can be expected to be modest.
c) Industry processes: a liberalised model for meter availability generates additional transaction costs compared to monopoly. In particular, in case different gas and electricity retailers procure meter availability services from different meter companies, supplier's switch triggers a series of transactions and information exchanges related to metering which are not necessary in a monopoly setting.
d) Expected competitive dynamics: due to high fixed and sunk costs and the possibly limited number of active firms, it is not clear whether effective competition in meter availability services can be sustained. In particular, high sunk cost result in the consumer and the provider being locked in a long-term relation, which may result in prices above competitive levels.
e) Geographic scope of monopoly in meter availability services: the very diverse size of existing meter operators suggests that European electricity and gas markets are large enough to accommodate multiple meter operators, each above minimum optimal scale.

Regarding data management, the latter shares with meter availability some characteristics which affect the relative merits of liberalisation and monopoly. These are reliance on standardisation and the need for the multiple transactions and information exchanges in case of energy supplier switch, in a setting with competing suppliers of data management services.

However, the cost structure of data management services makes them suitable for periodic selection of a provider through some form of competitive process, in which the provider is selected based on the price and possibly content of the service offered.

Summing up, the report's economic analysis suggests that scenario 3 would best serve consumers' interests.

Finally, the reorganisation of meter services raises the issue of the role of energy distributors. In most countries, the latter have traditionally been monopoly providers of metering services. In this respect, the report concludes that while the evolution of the energy industry's organisation has weakened the case for the distributors' role as suppliers of metering services, some specific features of the distribution activity still provide grounds for extending their monopoly to meter availability services. However, those features do not appear to provide justification for extending such monopoly to data management.

In addition, concerns that distributors carry out metering activities in a way that discriminates in favour of their affiliate retail business have been expressed in some European countries. These concerns would be fully addressed by assigning data management responsibilities to a party not active, directly or indirectly, in the retail market.

Legal assessment

From a legal perspective, Scenario 1 is the easiest, since it conforms to the starting point under EU law, namely competitive markets, without any intervention such as mandatory roll-out obligations or legal monopolies. In practice, however, some "supporting" regulation would be needed for competitive market to work. For one, standardisation of various elements of smart metering – from the interfaces on the meter themselves to the protocols used for data communications – is unlikely to be problematic under EU law, unless it leads to fragmentation of the internal market.

Considering the potential for innovation in, and mostly around, smart meters, it is advisable to standardise smart meters around a relatively simple and open model. This would leave room for future innovation to take maximum advantage of the installed base of meters.

Mandatory roll-out (as it is envisaged in many Member States), whereby one or more operators are put under an obligation to install meters for all customers in a given territory, could be justified by e.g. the need to reach a critical mass of smart meters, to overcome a time discrepancy problem or to address externalities.

In principle, Member States may grant a *legal monopoly* on meter availability or data management, pursuant to Article 106(1) TFEU. However, such a monopoly is vulnerable to attack for leading to competitive distortions, for instance because the scope of the monopoly would be excessive or because the monopoly holder would engage into anti-competitive practices on other markets where it is present.[3] The monopoly would then have to be shown to be necessary and proportionate for the fulfilment of a Service of General Economic Interest (supply of electricity, gas or water). Factors that reduce the likelihood that a monopoly would be curtailed include: the monopoly is entrusted to a third party without any other role in the sector, it is of limited duration and it is awarded via a procurement process which creates competition for the market. Furthermore, awarding a monopoly without a mandatory roll-out obligation is more difficult to justify, and a monopoly on data management is harder to justify than on meter availability services.

In any event, irrespective of regulatory intervention in the organisation of smart metering, legal issues also arise as regards the policing of the behaviour of smart metering firms.[4] Competition law can deal with such issues, but it is advisable to consider regulating the behaviour of firms, if they hold a legal monopoly or are expected to be *de facto* dominant. Such regulation could comprise obligations of transparency and non-discrimination, for instance.

In addition, the report also explores the main issues surrounding privacy and data protection law, as it applies to smart metering, namely the presence of personal data, the role of the data

[3] It is also possible that a monopoly on meter availability held by the DSO would be held to fall under scope of "distribution" for the purposes of energy or gas regulation, and thus allowed by EU secondary law.
[4] In the EU, regulatory intervention neither excludes the application of EU competition law, nor does it bind EU competition law analysis, as regards for instance market definition.

controller, the purposes for which personal data can be collected, as well as the requirements that smart meters employ Data Protection by Design and comply with Data Protection Impact Assessments. Data protection law is expected to apply to all actors involved in smart metering, and to that extent it does not significantly affect the regulatory design.

1. Introduction

Meters are devices that measure electricity, gas or water consumption. Meter data is necessary to settle retail transactions – between energy or water supplier and consumer – and transactions between unbundled providers of inputs such as transportation services on transmission and distribution networks.

Smart metering introduces new features such as meter reading automation, collection of high-frequency consumption data and, in some implementations, the ability to implement remote activation/deactivation of supply, set withdrawal ceilings and remotely control consumer's electric appliances or distributed generators. These features are expected to yield benefits in several areas: retail service quality and cost, demand response, energy and water conservation, distribution service performance and cost, electricity system operations and industry processes.

Smart metering is expected to enable the development of a variety of energy-related services based on high-frequency consumption data. This report does not deal at length with those services, because no obstacles to their competitive provision – and hence no need for specific regulatory intervention – have been identified so far. They are taken into account, however, when innovation is brought in the analysis, to the extent that innovation expected to occur in relation to smart metering will take place in relation to such services.

Large-scale deployment of smart metering systems in network industries – currently discussed in many and implemented in few European countries – raises a number of technological, economic and legal issues.

Most Member States have completed the national cost-benefit analysis provided for in EU law, and the Commission is about to publish its assessment of these analyses.

Accordingly, at this time, enough information and data is available to make a tentative assessment of the situation and to develop policy recommendations, before the implementation stage starts in all EU countries.

This report follows the CERRE approach: it is multi-sectorial, multi-disciplinary and takes a pan European perspective. Concretely, most of the discussion concerns electricity and gas. To the (limited) extent possible given the comparative lack of material, the analysis is also extended to water. Economic and legal issues are addressed in an integrated way. Finally, the report's geographic scope covers several EU Member States, including in particular the UK, France, Germany, Italy and the Netherlands.

Chapter 2 of the report presents smart metering, discusses its expected benefits and costs and surveys cost-benefit analyses performed in some European countries.

Chapter 3 presents the technical aspects of smart metering.

Chapter 4 provides economic and legal analyses of the regulatory design choices available to Member States. Those choices are expressed in the form of alternative scenarios.

Finally, chapter 5 explores whether privacy and data protection law should influence regulatory design.

2. Smart metering in energy and water sectors

This chapter introduces the role of metering in electricity, gas and water supply – in section 2.1 – and discusses the benefits and costs of large-scale deployment of smart meters. It then surveys the results of cost-benefit analyses carried out in selected European countries – in section 2.2. In that context, the choice of mandating smart meter deployment, as opposed to allowing consumers to decide whether to adopt (and pay for) smart meters, is assessed.

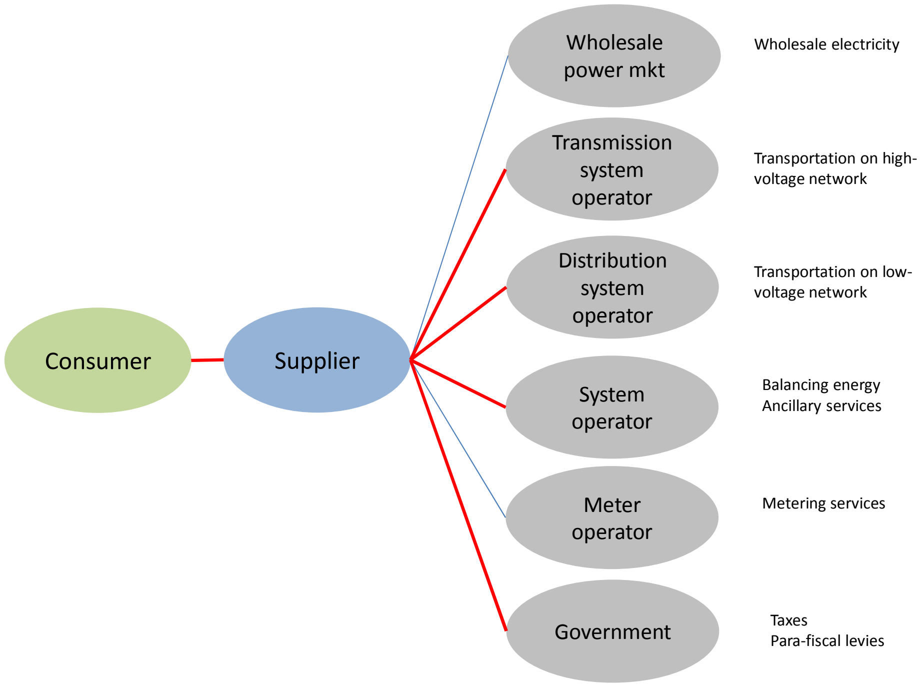
2.1 The role of metering in electricity, gas and water supply

Electricity, gas and possibly water supply involve several transactions settled based on metered data. Electricity transactions are discussed first, as they are more complex. Specific features of gas and water transactions are subsequently highlighted. The presentation is casted in the context of stylised institutional arrangements, tariff and price structures.

2.1.1 Energy and water transactions

Figure1 illustrates the parties involved in the supply of electricity to a consumer. The red lines represent transactions based on metered consumption data.

Figure 1 - Parties involved in transactions related to electricity supply[5]



Suppliers design offers, issue invoices, collect payments and act as single point of contact for electricity consumers. The consumer's electricity bill depends on metered consumption.

The supplier procures all inputs necessary to supply service. Firstly, the supplier purchases on the wholesale market a volume of electricity matching its clients' consumption. The system operator enforces the supplier's commitment to withdraw electricity bought on the wholesale market. In practice, the supplier notifies to the system operator the volume bought on the market. Then, metered consumption by the supplier's clients is compared with the notified volume. Finally, the supplier pays the system operator for electricity that its clients consumed in excess of the notified volume or it receives payment by the system operator for volumes notified but not consumed. In

[5] Source: authors. Throughout the document, the absence of specific source indication means that the information, figures or tables come from the authors.

this way, commitments entered into on the wholesale market are financially enforced.[6] This process is known as “imbalance settlement”. In addition, each supplier pays the system operator a share of the cost incurred to run the system, such as the cost of reserve generation capacity. System operation costs are typically split among suppliers based on their clients’ metered consumption.

Secondly, the supplier buys transportation services from the transmission and distribution system operators. The charges for these services are (also) typically based on metered consumption of the supplier’s clients.

Thirdly, the supplier buys metering services; these services are charged on a per metered point basis.

Finally, quasi-fiscal price components, such as levies to support renewable generation, are collected by the supplier. These charges too are usually assessed on the basis of metered consumption.

Since meter details the basis for settlement of multiple transactions in the electricity industry, several parties have to trust the information provided by the meter located at the consumer’s premises. In the rest of the report, parties involved in transactions based on meter data will be referred to as “data users.”

When a consumer switches supplier, multiple parties need meter related information. In particular, the consumed volume up to the switch date needs to be known in order to settle pending transactions between, on the one side, the incumbent supplier and, on the other side, input providers and the consumer. In addition, all providers of inputs must be notified the identity of the entrant supplier, who will take financial responsibility for services provided at the consumer’s supply point.

[6] On the design of electricity transactions, see for example chapter 2 of *The economics of electricity markets*, P. Ranci and G. Cervigni eds., Elgar, 2013.

2.1.2 Product standardisation and profiling

In most wholesale electricity markets the basic traded product is the hourly block; that is production or consumption taking place over a fixed hour, irrespective of the time pattern of injections or withdrawals within the hour. Hourly products mean that charged rates may vary according to the hour of consumption.[7]

Product standardisation is taken a step further in the retail market, (also) due to metering. Most of the electricity meters currently in place at small consumers' premises do not record hourly consumption, but only total withdrawal over a longer period.[8] Conventional mechanical meters, still widely in use, only indicate total energy consumption since they were installed. Therefore, only total consumption between two readings is known.[9] This has two main consequences.

First, in order to assess whether a supplier has procured electricity injections (offsetting its clients' withdrawals), notified and actual hourly volumes need to be compared. This is so because on the wholesale market the electricity price is different in each hour. For this purpose, the consumer's total withdrawal over the metering interval is conventionally split among the hours of the interval. This process is known as load-profiling.

Second, the supply price to non-hourly metered consumers cannot be contingent on the actual pattern of consumption, which is not measured, but only on the total consumption over the metering interval. Therefore, demand by non-hourly metered consumers is price-insensitive within the metering interval, because these consumers face the same (retail) price irrespective of whether they consume at times of high or low wholesale prices.

[7] Product standardisation is crucial to make electricity trading possible because the value of electricity continuously varies over time and therefore, absent any standardisation, the number of traded products would be unmanageably large: electricity delivered in one minute would be a different product with different price from electricity delivered the following minute. Hourly standardisation strikes a balance between cost reflectiveness of prices and transaction costs.

[8] Consumption by larger consumers is typically measured hourly or half-hourly. Small consumers are typically equipped with non-hourly meters. More recent meters for residential consumers record only total consumption in each of a few given time bands. For example, consumption occurred between 8.00 and 22.00 and between 22.00 and 8.00.

[9] Small consumers' meters are typically read one or two times per year.

2.1.3 Gas and water transactions

Like electricity, most gas and water meters currently in place record total consumption. This implies that only withdrawals between two readings can be assessed.

However, the natural gas' value is generally perceived as less volatile than electricity's.[10] The basic standard traded product in most wholesale gas markets is therefore the daily-block. That is the volume of production or consumption taking place over a day, irrespective of the time pattern of production or consumption within the day. The price for water is generally independent of the time of withdrawal and in some countries water tariffs do not reflect any opportunity cost of water usage. Assessing whether such pricing reflects real demand/supply conditions or whether it is a regulatory distortion is beyond the purpose of this research.

In terms of supply chain, natural gas and electricity supply present several common features. In particular, the supplier's role and the design of transactions on inputs are similar. Gas suppliers purchase: natural gas on the wholesale market; transport services in high-pressure (transmission) pipelines; storage services in storage facilities; transport services in low pressure (distribution) networks. As for electricity, the supplier's commitment to inject in the system a volume of gas matching consumers' withdrawals is financially enforced ex-post, by comparing metered withdrawals and supplier's notifications. Most of these transactions are based on metered consumption data.

On the contrary, water is typically supplied by vertically integrated (local) monopolies; therefore, meter data are mainly if not exclusively relevant to invoice consumers.

2.2 Benefits and costs of smart metering

Expected benefits and costs of large-scale deployment of smart meters are discussed in this section. First, the nature of the benefits that smart metering is expected to deliver in the energy and water industry is identified. Then, the results of cost-benefit analyses carried out in some European

[10] Natural gas is more easily stored than electricity.

countries are reviewed. Finally, the issue of optional vs mandatory deployment of smart meters is addressed.

2.2.1 Expected benefits of smart metering

Smart meters can be expected to deliver benefits in the following areas: retail services, demand price response, energy conservation, distribution services and system operations, metering services and industry processes.

Retail service quality and cost

Meter data are collected from traditional meters through visual inspection. This requires that either a supplier's representative accesses the consumer's premises or the consumer reads the meter's display and notifies the supplier.

The burden placed by manual meter reading on the supplier and/or the consumer is such that commonly just few meter reads per year are taken, typically one or two. Billing, instead, is typically carried out every month or every few months based on estimated consumption. Estimated billing may result in the consumer receiving large settlement bill once meter is read. That may result in debt by consumers with poor financial management.

Meter reading automation, which reduces the cost of incremental readings, is a basic feature of smart metering systems. As a consequence, the need for estimated billing virtually disappears when smart meters are deployed. This is expected to reduce the supplier's cost of handling disputes and complaints.

Further, frequent meter readings ease customer's financial management. They enable suppliers to identify consumers at risk of building up debt and also to take preventive measures, for example, by warning a consumer about abnormal consumption and providing him or her with energy efficiency advice. Smart meters reduce also the cost of recovery of outstanding debt, by reducing the cost of interrupting service, enforcing a cap on power withdrawal or switching from credit to prepayment service.

Smart meters reduce the cost of implementing changes which would otherwise require access by an engineer to the consumer's premises. In particular, smart meters allow to remotely:

- activate or interrupt service;
- set the level of maximum power withdrawal before automatic cut-off. This feature allows, for example, to deliver a minimum, vital service to consumers in debt, a less disruptive alternative than interrupt service;
- settle level of total energy withdrawal before cut-off, which reduces prepayment implementation cost.

Finally, smart meters make detection of tampering and theft attempts quicker. Expectation of quick detection of and reaction to theft attempts may discourage such behaviour and reduce supply cost.

Energy demand response

In general, the meters installed at small consumers' premises only indicate total withdrawal since the time of the meter's activation. This only allows computation of the consumer's withdrawal between two readings. At best, small consumers' meters record total consumption over a period of up to one month. Smart meters, instead, allow collecting high-frequency consumption data.

Availability of, say, hourly consumption data is prerequisite for implementation of prices that vary depending on the time of consumption, or "time-of-use prices". Through time-of-use prices consumer can be exposed to the cost caused by his/her behaviour. This is shown in Figure 2.

Figure 2 - Impact of time-of-use retail pricing on wholesale price volatility

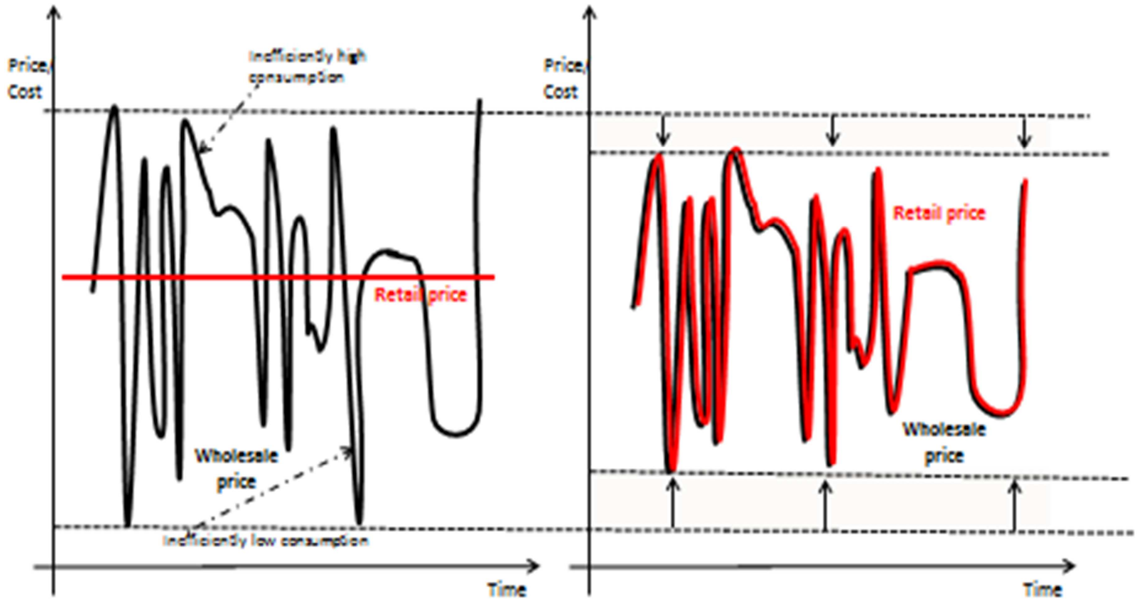


Figure 2 represents wholesale (hourly) and retail market prices over a certain period, for example a quarter. The left panel of the figure is relevant when traditional meters are in place. Those can only record total consumption during the period. In that case, only a uniform retail price can be implemented because it is impossible to determine how consumption was split among different hours of the metered period. Competition among retailers would push such uniform price towards the weighted average of hourly wholesale prices. Here weights correspond to the conventional profile used by the system operator to allocate consumers' load among hours when assessing the supplier's net energy position in each hour in order to charge imbalances.[11]

The right panel represents pricing made possible by smart meters. Since consumption in each hour can now be recorded, time-of use prices may be implemented. In particular, wholesale prices may be passed-on to consumers.

[11] See previously, section 2.1.2 regarding load profiling.

Provided the consumers' preferences are such that their willingness to consume energy and water is price dependent, time-of-use pricing is beneficial as it may shift demand to off-peak periods. In high price hours consumers on time-of-use prices consume less than they would in case they were charged an average price, while in low price hours they would increase consumption. As a consequence, by reducing load volatility, time-of-use pricing may lead to:

- smoother wholesale price pattern and fewer instances of physical rationing (*brown-outs*);[12]
- less need for generation and transportation capacity;[13]
- smaller operating reserve requirements;
- lower emissions;[14]
- market power mitigation in wholesale electricity market.[15]

Since electricity is not economically storable on large scale and demand and supply conditions vary continuously in time:

- the value of electricity consumed and produced at a certain time – the "time of delivery" (or "real time") – can be reliably assessed only very close to that time. This is so because actual demand and supply conditions at the time of delivery can be correctly anticipated only a short time in advance;

[12] When price independent demand turns out to be greater than available capacity physical rationing must be implemented, i.e. service to some consumers is interrupted. When that happens the wholesale market price for electricity should be set equal to so called Value of lost load (VoLL), an administrative set price level such that consumers should be indifferent between paying VoLL and not consuming. The drawbacks of this solution are presented, for example, in chapter 3 of *The economics of electricity markets*, P. Ranci and G. Cervigni eds., Elgar, 2013.
[13] Reducing transmission capacity investment is among the main explicit objectives of the German smart metering program.
[14] A smoother load pattern may reduce the need for ramping up and down thermal generators, whose efficiency is lower in dynamic conditions. Further, in most electricity systems the generation mix during peak period is more carbon intensive than off-peak.
[15] When price-independent demand approaches available capacity, small reductions in supply may cause large price increases. In other terms generators have strong incentives to exercise market power. Market power mitigation measures may be introduced as a surrogate of demand response to prices, but, as all administrative intervention, they are not without problems. On market power in wholesale electricity markets see for example chapter 3 of *The economics of electricity markets*, P. Ranci and G. Cervigni eds., Elgar, 2013.

- all electricity transactions but those taking place near real time have future nature; therefore their prices can turn out to be very different from the real-time price, which reflects actual demand and supply conditions.

Demand response, enabled by smart meters, can be implemented in different time frames: forward or real time. Forward transactions require consumers to commit to certain consumption behaviour well in advance of real time. For example, the consumer could receive price notifications the day before delivery from his supplier. He would then plan next day's consumption based on those prices.[16] An alternative approach to implement forward demand response is based on the consumer's selling flexibility, for example in exchange for a discount on supply prices. In this approach, the consumer commits to follow indications – typically in the form of constraints on maximum withdrawal – notified by his supplier the day ahead of consumption.

The arrangements described so far make electricity demand responsive to forward prices. However, in case real-time price turns out to be, for example, much higher than expected the day before delivery, demand will not be reduced. This suggests that the benefit of forward demand response is higher if real-time prices can be accurately predicted, i.e. the closer forward prices are to real-time price. In this perspective, the increasing share of intermittent renewable generation capacity – such as solar and wind – can be expected to reduce, *ceteris paribus*, the value of forward demand response, because:

- solar and wind have almost zero variable cost, resulting in moderate forward price variability across different levels of demand; in other terms, in a typical forward timeframe, such as day-ahead, a generation park with a large renewable component will result in prices broadly similar for a large range of demand levels;
- sun and wind conditions are reliably predictable only a short time in advance, therefore real-time prices may turn out to be much different from forward prices.

[16] Traditional time-of-use tariffs are a rough instance of this kind of arrangements. Some traditional meters allow recording total consumption in certain sets of hours (or time-bands). For example, the meter might be able to separately record total consumption in the time bands 8.00 to 20.00 and 20.00 to 8.00. Since consumption in each time band is known, consumer can be charged a (different) price for consumption in each time-band. Notice however that traditional multi-time meters would record total consumption, per each band, only over a very long time, possibly only since the meter was activated; therefore time-band prices could not be changed often.

The potential for small consumers to adjust consumption close to real time is largely untested. Over time, introduction of heat pumps with storage capacity and development of electric transportation may increase the amount of flexible load.

However, in order to elicit real-time demand response, consumers – or more likely the consumers' electrical appliances – must continuously receive and elaborate price notifications or load-management commands. That suggests that, enabling small consumers to adjust demand close to real-time requires massive investment and the development of a large body of new technical, commercial and organisational arrangements.[17]

Finally, since the value of short-term demand response depends on price variability, it is lower for gas and even more for water than electricity. In particular, gas storability results in price cycles spanning over much longer periods. A more general problem holds for water. The very idea of pricing water is generally highly politically unpalatable. In some countries, this results in prices for water services that do not properly reflect cost. In that context, it is hard to think of smart metering as delivering benefits in terms of demand time profile.

Energy and water conservation

Greater consumer awareness about cost and environmental impact of energy consumption is expected to trigger efforts to reduce consumption. Smart meters contribute to increasing consumer awareness by making continuous monitoring of consumption and expenditure possible.

Field trials provide evidence of energy savings associated with the introduction of smart meters. The UK Department of Energy and Climate Change (DECC)[18] has carried out a survey of available studies seeking to quantify the impact of smart meters on energy demand. In particular, DECC finds that trials more closely comparable to the British roll-out showed statistically robust electricity

[17] For an assessment of real-time price elasticity, see for example M.G. Lijesen, The real-time price elasticity of electricity, *Energy Economics*, 29, 2007.
[18] Department of Energy & Climate Change, *Smart meter roll-out for the domestic and small and medium non-domestic sectors (GB), Impact assessment,* January 2013, IA No: DECC0009.

savings of 2% to 4%, in case in-home displays were or were not installed. In gas, without in-home display, savings of around 3% were found.

In principle, a similar mechanism could operate with respect to water conservation. However, policy discussion on smart metering in the water industry is not yet developed and no quantitative assessment of the impact of smart metering on water consumption is available.

Distribution and distribution-level system operations

Smart meters provide information on the quality of the electricity and gas services delivered to consumers, such as variation of voltage amplitude, transient voltages and currents and harmonic content in the waveforms – for electricity – and pressure and temperature – for gas.

Further, they may ease identification of network fault location. This is so since the distribution system operator can remotely check the "energisation" status of any meter in the system. In addition, some meters can actively send a message in case of outage or gas leakage.

Smart meters provide information that may be useful for network planning. In particular, historic information on the power flows and voltage across the distribution network allows assessing more accurately the network's capacity to host embedded generation.

However, smart meters installed at the consumers' premises are not necessary to obtain information on quality of service and power flows across the distribution network. In fact, a much smaller number of meters installed at power substations may provide adequate information for the purpose of assessing quality of service and the need for network upgrades.

Finally, in some implementations, the smart metering system is capable of conveying remote control signals to the consumer's electrical appliances, including embedded generators such as photovoltaic panels installed at the consumer's premises. This allows the distribution system operator to shed such load or generators in case the network cannot securely host, respectively, withdrawals or injections. Greater control by the system operator of distributed generators may, *ceteris paribus*, allow connecting to the network a larger renewable capacity.

This report addresses the potential contribution of smart meters to expanding the role of price signals in order to obtain efficient energy market outcomes as a result of voluntary consumption, generation and, where feasible, storage decisions. However, a smart metering system can also be used to implement administratively decided load or generation curtailment. A discussion of alternative institutional arrangements for distribution system operations is beyond the purpose of this report.

Water distribution networks are generally less meshed than gas and electricity networks and system operation issues are less critical. However, a smart metering infrastructure may make detection of leakages easier and quicker.

Reduction of green-house gas emissions

Reduction of green-house gas emissions is a key objective of smart metering policies in Europe. We have previously discussed how smart metering is expected to contribute to reducing emissions, in particular by:

- reducing energy consumption;
- reducing demand volatility, to the extent that this results in lower utilisation of less efficient generators;
- increasing the distribution network capacity to connect (renewable) distributed generation.

The next section discusses to what extent this objective motivates mandatory adoption of smart metering systems.

Metering service

As discussed above, smart meters make high-frequency consumption data available. Compared to traditional technology, they also reduce the cost of frequent data collection by removing the need for site visits to complete meter readings. In addition, smart meters feature automatic fault and tampering detection systems. These features reduce meter and data related disputes.

Industry processes

Timely and reliable information on energy consumption provided by smart meters is beneficial for a wide set of transactions and processes in the energy industry.

In particular, timely availability of meter readings streamlines the process to switch supplier, as all transactions involved in supplier switch may be swiftly settled based on actual consumption.

Meter reading automation reduces the scope for reading errors and the corresponding cost of handling complaints and "misbilling". More generally, complex settlement and reconciliation processes, which may result in disputes, can be dispensed with, once smart meters make consumption estimation unnecessary.

Since vertically integrated monopoly arrangements are prevalent in water supply, smart metering can be expected to deliver more modest benefits to industrial processes in water compared to the gas or electricity sector.

2.2.2 Smart metering cost structure

Smart metering costs can be grouped in the following broad categories:

- meter and communication assets installed inside the consumer's premises;
- head-end assets and data services;
- communications.

The content and level of each cost category depends on the smart metering architecture. Alternative architectures are presented in chapter 3 of this report.

Capital cost for equipment installed inside the consumer's premises account for the largest share of smart metering costs. For example, in the UK, such cost is expected to account for at least 75% of the total.[19,20]

Head-end cost is the cost to collect, elaborate and make available meter data. Together with communication costs to transfer meter data from the consumer's premises to the head-end system, those costs have been estimated to account for an additional 17% of total cost in the UK.[21]

2.3 What can be learned from cost-benefit analyses run in some European countries

This section reviews the cost benefit analyses of smart metering systems carried out in selected EU Member States. This discussion focuses, in a first stage, on the choice made in most of these countries to mandate deployment of smart meters rather than to allow consumers to decide whether to purchase smart metering service. The actual results of the cost benefit analysis are then assessed.

2.3.1 Mandated vs optional smart metering

The past experiences with competitive markets for smart metering, for instance in Great Britain or Germany, revealed that customer take-up is limited. In all countries examined, it can be observed that public authorities have decided not to rely on market forces alone. They are imposing mandatory roll-out obligations on one firm (or many).[22] That firm must then install smart meters on customer premises, irrespective of commercial considerations. Similarly, customers must then accept the use of a smart meter, for which they usually pay directly or indirectly.[23] The sole

[19] Figures in this section merely provide an order of magnitude. They are based on data reported in "Smart meter roll-out for the domestic and small and medium non-domestic sectors (GB) Impact Assessment", DECC 2013.
[20] Including additional energy consumption by smart meters.
[21] Including additional cost for manual reading during the transition period.
[22] Usually one, but Great Britain is imposing a roll-out obligation on all energy suppliers.
[23] Mandated deployment of smart meters may echo universal service policies implemented in other industries, including post and telecommunications. However, both policies reflect different objectives and use different tools. Universal service policies focus on ensuring service availability to all consumers irrespective of differences in cost of service, typically implementing some form of cross-subsidisation among consumers. Roughly, the idea is that all consumers would purchase the service if they were charged price equal to the average supply cost, but some consumers are much more

exception is the Netherlands, where current policy is that customers may refuse the installation of smart meters or require that they remain idle once installed. Possible justifications for mandated deployment are discussed next.[24]

Critical mass

Some benefits of smart metering programs might materialise only if at least a certain number of consumers participate. Economies of scale in the deployment of smart meters are an example of such benefits. Reaching critical mass poses a coordination problem: each party would participate in the project if all others did, but no one would do it alone. Consider for example the case in which critical mass is required to bring cost for smart meters down to a level where the project's net value is positive.[25] Mandated deployment is a straightforward way to solve such coordination issue.

However, market players can also address coordination issues without public intervention. For example, suppliers might collect from clients the commitment to purchase a smart meter at the (low) price consistent with large participation in the program, while making actual deployment subject to critical mass being reached. In this context, impossibility to reach critical mass would signal that the program has a negative net value.

In the absence of any other imperfection, coordination issues do not necessarily require mandated deployment.

Externalities

Property rights on some benefits from smart meters might not be enforceable. In particular, it might be impossible to transfer to consumers, who pay for it, the benefit resulting from deployment of the smart metering system.

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expensive to serve than the average. These consumers would not buy the service at a price equal to the cost they cause. Universal service policies aim at allowing those consumers to receive service. On the contrary, mandated deployment as being implemented in smart metering entails an imposition on all consumers to buy smart metering services.

[24] See for example Department of Energy & Climate Change, *Smart meter roll-out for the domestic and small and medium non-domestic sectors (GB), Impact assessment*, January 2013, IA No: DECC0009, p. 12.

[25] Network externalities can be another source of critical mass issues in telecommunications. See for example M. Katz C. Shapiro, Technology adoption in the presence of network externality, *Journal of Political Economy*, Vol. 94, 1986.

Cost-benefit analyses indicate that the single largest benefit that consumers are expected to obtain from smart meters is lower energy bills due to reduced energy consumption. Provided energy prices reflect correctly the social value of lower consumption, the consumer's incentives to reduce consumption are in line with the social incentives, and no (further) measure is needed. More generally this holds for all benefits related to wholesale energy prices, such as greater consumer's surplus resulting from the ability to consume less when prices are high and more when prices are low, or from lower market power exercise by generators.[26]

Smart metering benefits in terms of quality of retail service do not appear to involve direct externalities: for example, only consumers purchasing smart meters would avoid estimated billing and would not receive meter reading visits. Further, smart meters would facilitate smoother and quicker supplier switch for those consumers. Therefore, no direct externality is involved.

Other benefits accrue to suppliers in the form of reduced retail cost. Competition is meant to force suppliers to transfer any cost reductions obtained thanks to smart meters to consumers, in the form of lower supply prices. No externality is then present. In particular, if it turns out that consumers with smart meters can be served at lower cost, suppliers will offer them, all other things being equal, lower prices. Finally, some of the benefits of smart meters accrue to distributors. Those benefits may be passed-on selectively to consumers who have decided to purchase smart meters via regulation, in particular in the form of lower distribution tariffs. Not even in this case, then, an external effect is present.

Finally, recall that environmental benefits are commonly expected from smart meter deployment. As far as mandatory adoption is concerned, we note that the European cap and trade approach to control CO2 emissions is based on internalising the cost of CO2 emissions in wholesale electricity prices. In this approach, then, wholesale electricity prices are supposed to reflect also the environmental impact of energy consumptions. Therefore, electricity prices are meant to provide

[26] Recall that demand inflexibility makes it necessary to administratively set the wholesale price for electricity in case demand is greater than available generation capacity and planned black-outs are implemented. This administrative price, the VoLL, is an imperfect substitute for a demand function reflecting the consumers' real preferences. One may argue that, if VoLL is set too low, the incentives for a flexible-demand consumer to buy a smart meter are inefficiently low. However, this situation appears to reflect more a flaw in VoLL-setting than to provide a justification for mandatory adoption of smart meters.

correct incentives to consumers to buy smart meters in order to reap the benefits of reduced consumption. More generally no externality justifying mandatory deployment is present in case the price system reflects the environmental cost of energy consumption.

The CO2 emission scheme does not cover gas consumption by small consumers. Therefore, there could be external benefits in reducing gas consumption thanks to the introduction of smart meters. However, we have argued before that the scope for (and value of) gas demand price responsiveness is smaller for gas than for electricity. We note further that policies implemented in the EU to reduce gas consumption do not appear to be connected with smart meter deployment: for example subsidies for the replacement of domestic heating systems are typically targeted to more efficient boilers, irrespective of their capabilities to connect to a home-intelligence system.

The assessment that environmental externalities provide little or no justification to mandatory deployment of smart meters appears to be reflected in all cost benefit analyses we examined. In particular they do not include such externalities among the benefits of smart metering and alternative measures targeting those environmental benefits are considered in counterfactual scenarios.

Information asymmetry

In deciding whether to purchase smart metering services, consumers might not fully consider future benefits delivered by smart metering. The foundation for mandated deployment would then be that the public decision maker enjoys superior information on the benefits that consumers themselves will obtain from smart meters.

In fact, the main benefits expected from smart metering – energy savings and quality of the retail services – have the same nature as the benefits that consumers regularly assesses, for example, when selecting their electricity supplier or price option: cost and quality of the service. This suggests that no fundamental information issue would affect private decision making on smart metering.

It can be argued that the time horizon of decisions related to smart metering is much longer than for other decisions that consumers efficiently make in autonomy and that some form of consumer's myopia provides justification for public intervention. It is difficult to assess the size of this possible misalignment.

More generally, the line of justification of mandated deployment based on the public decision maker's information advantage over citizens' touches political issues that are beyond the scope of this report.

Technical interoperability

As discussed in detail in chapters 3 and 4, a great deal of technical standardisation is necessary to ensure interoperability of the different elements of a smart metering system. Public intervention may facilitate such coordination.

However, mandated deployment is neither necessary nor sufficient to ensure interoperability, because the need for standardisation is largely independent from the number of smart meters installed.

Commercial interoperability

Commercial interoperability as a reason for mandated deployment of smart meters has been put forward in the UK, where electricity and gas suppliers are responsible for installing smart meters. In case smart meter installation is not mandatory, meter owners face the risk of losing the value of the meter when customer switches energy suppliers, because the receiving supplier might be unwilling to use the smart technology and, therefore, cover full cost of the meter.[27]

This concern could be more directly addressed if smart meter adoption was voluntary. Indeed, in that case the decision to have a smart meter would ultimately be made by the consumer. That would justify a regulatory imposition on the entrant supplier to cover full cost of the smart meter

[27] As discussed in chapter 4, hold-up issues are crucial determinants of the nature of (and scope for) competitive interaction in the supply of some smart metering services.

that it finds installed at the consumer's premises, irrespective of whether the meter's smart features are actually used.

As a result, a consumer who once decided to install a smart meter would bear the corresponding cost irrespective of the selected supplier; the meter's owner would be guaranteed full cost recovery.

Inadequate features

In the UK context, it was argued that, absent mandated deployment, some suppliers might only deploy a smart metering system that maximises their own cost savings, but might not deliver full benefits to consumers.

However, absent any other imperfections, such outcome would correctly reflect the consumers' willingness to pay for smart metering features. Therefore, it cannot be assumed to be inefficient.

Indirect network effects

The following argument in favor of mandatory adoption of smart metering often surfaces the policy debate: innovative value-added third-party solutions will only be developed if there is a sufficiently large consumer base. Conversely, a sufficient number of consumers can only be expected to join if those solutions are in place.[28]

This line of reasoning evokes a situation with:

a) multiple stakeholders: the electricity consumers and the providers of innovative services based on meter data;
b) services that do not exist when the decision to deploy smart meters is made and that will be developed only if a sufficiently large base of smart meters is installed.

[28] The authors are grateful to Martin Peitz for suggesting this formulation of the indirect externality argument.

First, the impact of multiple stakeholders is considered. The assumption is that the value added services have been conceived, even if they are not yet developed when the opportunity to deploy smart meters is considered. The innovation dimension is then added to the picture.

In order to illustrate the coordination issues which this argument is based on, consider for example the following situation: each electricity consumer would find paying for a smart meter worthwhile if he could then buy three advanced services based on meter data, each of these services being supplied by a different provider. However, if just one of those services was not available, the consumer would not want to purchase a smart meter. On the supply side, each of the (would-be) providers of advanced services would find it profitable to enter the market only if at least a certain number of consumers had smart meters. The special feature of this example is that none of the bilateral transactions between the consumer and one of the advanced service providers, individually, creates enough value to justify buying a smart meter, even though the three transactions together do. This feature makes the coordination problem more difficult compared to the one previously discussed.

Yet in a frictionless world, mandatory purchase of smart meters does not appear necessary to address this coordination problem. For example, one of the service providers might offer its service at a price that makes it attractive to (a sufficiently large number of) consumers, while bearing the smart meters' cost, provided it is then allowed to sell metering services to the other suppliers of advanced services once these enter the market. Alternatively, the would-be suppliers of advanced services could merge and offer the three services as a bundle, which would make consumers keen to purchase smart meters. Or one of the suppliers might develop services that are substitutes to those offered by the other two providers and sell them as a bundle, inducing consumers to purchase smart meters voluntarily.[29]

The innovation dimension adds a further level of complexity to the situation. In the above example, assume that consumers are not aware that, in case enough of them purchased a smart meter, value

[29] Finally, it is possible that, in time, services will be developed that justify, individually, introduction of smart meters. For instance, one may conjecture that an electric car dealer would be keen to include a smart meter in a bundle with a car, in exchange for a two-year commitment on behalf of the buyer to feed his vehicle from the dealer's affiliate electricity supplier.

added services would be introduced which would make the smart meter worth having. In this situation, the public authority, better informed than consumers on the scope and value of innovative services that will be created in case enough smart meters are installed, could beneficially mandate purchase of smart meters. This line of reasoning has been addressed above under the heading “information asymmetry”.

Discussing the merit of this argument in practice is hard, because it is based on a diverging anticipation, by consumers and the public authorities, of an unknown future. We limit ourselves to noticing that in industries in which indirect network effects are at least as plausible as in smart metering, an impacting measure such as forcing consumers to buy of an enabling asset has not been implemented. This is for example the case of personal computers or Internet connectivity.

2.3.2 Cost-benefit assessments in Europe

The following table reports information on the results of cost-benefit analyses of smart meter deployment in the United Kingdom (or rather just Great Britain), Germany, France and the Netherlands. The discussion of the table covers also available information on cost-benefit analyses run for Italy and Belgium, for which quantitative information is not available.

Table 1: Comparison of cost-benefit analyses in different European countries

	Great Britain	France		Germany		The Netherlands
Sector (Scenario)	Electricity and gas	Electricity	Gas	Electricity (EU scenario)	Electricity (Roll-out Plus scenario)	Electricity and gas
CBA modelling period	2012 - 2030	2011 - 2038	2013 - 2032	2012 - 2032	2012 - 2032	2010 - 2060
Time frame for deployment	2014 - 2019	2013 - 2018	2011 - 2022	2012 - 2022	2012 - 2022	2014 - 2020
Number of meters (Mln)	**49**	**35**	**11**	**38.5**	**32.6**	**14.6**
Overall cost (€ Bln)	**14.4**	**3.8**	**1.2**	**20.8**	**13.7**	**2.8**
Roll - Out Investment costs (€ billion)	8.3	3.8	1.0	8.5	7	-
Operating costs (€ billion)	6.2	-	0.2	12.3	6.7	-
Investment costs per meter (€)	**168.5**	**108.6**	**94.8**	**220.8**	**214.7**	**192.1**
Expected benefits (€ billion)	**22.3**	**3.9**	**1.28**	**20.7**	**15.2**	**3.6**
Lower customer care costs (€ billion)	13.2	3.9	0.5	-	-	2.1
Energy conservation (€ billion)	7.7	-	0.2	-	-	1.5
Others (€ billion)	1.4	-	0.54	-	-	-
Net Present Value (€ billion)	**7.9**	**0.1**	**0.07**	**-0.1**	**1.5**	**0.8**

Notes:

1) Great Britain: all cost and benefit figures are based on “Smart meter roll-out for the domestic and small and medium non-domestic sectors (GB) Impact Assessment”, DECC 2013, pages 73 and 115. The number of meters and the time frame for deployment are taken from “Cost-benefit analysis for the comprehensive use of smart metering, Ernst and Young, on behalf of the German Federal Ministry of Economics and Technology, 2013, pages 72 and 73.” Figures are presented in euros, applying an exchange rate of 1.19 €/£. Roll-out investment cost is net of avoided cost of traditional meters in the counter factual scenario.

2) Unit investment cost is calculated as the ratio of roll-out investment cost and number of meters. It is intended as a proxy of the current cost of a meter point, including installation. For the Netherlands, roll-out investment costs are assumed to represent the same share of overall cost as in Great Britain.
3) France, electricity: Time frame for deployment refers to 90% of meters. Cost-benefit analysis is carried out only for the (major) distribution system operator. For that reason, energy conservation and other benefits are not accounted for. All figures are taken from *Dossier d'évaluation de l'expérimentation Linky,* Commission de Régulation de l'Énergie, 2011, page 25.
4) France, gas: all data from "*Etude comptage évolué gaz,* Poyry & Sopra Consulting, 2011", and "*Costi e benefici dell' introduzione di un sistema di smart metering nel settore italian o del gas*, Center for Research on Energy and Environmental Economics and Policy (IEFE), Università Bocconi, 2011". The value of energy conservation has been calculated based on known net present value, total costs and total benefits.
5) Germany: all data from "*Cost and benefit analysis for the comprehensive use of smart metering*, Ernst and Young, on behalf of the German Federal Ministry of Economics and Technology, 2013". The EU scenario assumes that 80% of all electricity meters will be installed by 2022. The roll-out plus scenario assumes selective deployment (consumers with above average consumption receive smart meters) and the possibility to curtail renewable generation. The relationship between smart metering and renewable curtailment is not clearly addressed in the cost-benefit analysis. In particular, the counterfactual scenario is not discussed. For example, the nature of avoided investments made possible by smart meters is not indicated. It is not clear either whether any cheaper way to implement renewable load curtailment is available, for instance by installing smart meters only in network areas where distribution networks are weaker and/or only for embedded generators. In the roll-out plus scenario, only 11.9 out of 32.6 million installations are full feature smart metering systems. The remaining 20.7 million are just intelligent metrological units. Intelligent metrological units do not allow remote collection of meter data until a smart gateway is installed. Therefore, the cost figure presented underestimates the cost of 32.6 million smart metering points.
6) The Netherlands: data from: Kema, *Smart meters in the Netherlands: revised financial analysis and policy advice*, 2010, page 58 and Ernst and Young, on behalf of the Federal Ministry of Economics and Technology, *Cost and benefit analysis for the comprehensive use of smart metering*, 2013, pages 72 and 82-85. Overall cost has been calculated as the difference between expected benefits and net present value in the reference scenario. The number of gas meters has been estimated to be equal to 90% of electricity meters based on information in the Kema report, at page 87, that in 2010, 90% of electricity users in the Netherlands were also gas users.

The above table suggests the following observations. First, cost-benefit assessments carried out in different countries are not directly comparable because projects considered in those countries differ in:

- *the sectors in which smart metering is implemented*: GB, France and the Netherlands assess deployment of gas and electricity smart meters; the cost-benefit analysis for Germany considers only electricity smart meters, even though the communication infrastructure deployed for electricity can support gas, water and heat meters too; Italy assesses deployment of gas meters only, while for existing smart electricity meters, no cost-benefit analysis has been published;[30]
- *the smart metering system architectures*: GB, Germany and the Netherlands consider multi-utility architectures; Italy and France contemplate independent gas and electricity metering systems. The approaches followed in GB and Germany are based on data concentrators (or gateways) located at the consumers' premises. Solutions being considered in France, Netherlands and Italy are instead based on neighbourhood level concentrators;
- *the smart meter features*: while solutions developed in GB and Germany place emphasis on remote load and generation control, Italy, France and the Netherlands solutions appear to be mainly oriented to automatic meter data collection;
- *the share of smart meters*: in Germany and the Netherlands a sizeable share of consumers are assumed, in some scenarios, to continue being metered in the traditional way. In particular, in Germany the highest net value program is such that about 20 out of 33 million installations will not feature basic smart meter functionalities such as remote reading. Other countries plan universal deployment of smart meters.

Further, the results of different cost–benefit analyses are presented with different levels of detail. At one extreme, the British methodology to evaluate each cost or benefit item is spelled out in

[30] Electricity smart meters were introduced in Italy under the condition that the tariff component covering metering costs would remain unchanged. In this way the regulator intended to ensure that consumers would obtain a non negative net benefit from the smart metering program. The decision to deploy smart meters was then the result of the distributor's comparison of traditional and smart metering cost.

detail. At the opposite extreme, only a summary of the Italian cost-benefit analysis is available and the Belgian analysis has not been published at all.

Second, cost-benefit analyses carried out in different countries reach different conclusions. In particular, the cost-benefit analyses related to GB, France and the Netherlands find that smart metering programs have net positive social value, while those focused on Germany[31], Belgium and Italy[32], at least for some scenarios and consumer groups, reach opposite conclusions.

Such large differences in cost-benefit assessments, as well as in the technological architectures considered among various European countries are not easy to relate to social or economic differences.

Third, some cost-benefit analyses indicate that smart metering is significantly more expensive than traditional manual metering. For example, a rough calculation, based on data reported in the GB cost-benefit analysis for gas and electricity smart meters for domestic and small, non-domestic consumers, suggests that, for each of the 49 million metered points, consumers will pay, over the next 18 years, 178 £[33] (2013 present value) in excess of what they would do for traditional metering.[34]

Fourth, in all cost-benefit analyses with the exception of France for electricity,[35] energy savings are crucial for smart metering projects to have positive net value.[36] The idea is that greater awareness of the implications of consumption behaviour would induce more efficient energy use and

[31] In Germany, electricity smart metering turns out to have positive net value only if associated with the possibility to curtail renewable generation. The Italian cost-benefit analysis for natural gas smart meters finds negative net value for consumers below 5,000 standard cubic meters per year, accounting for 97% of meter points.

[32] More recent statements by the Italian regulator indicate that, compared to the original cost-benefit analysis, larger benefits of smart metering are expected in terms of reduction in unpaid gas bills. See E. Bettenzoli, *Obiettivi degli ultimi provvedimenti dell'Autorità in tema di smart-metering gas*, CIG gas smart meters workshop, Bologna, 11 April 2013, downloadable from www.cig.it/workshop-gas-smart-meters/ .

[33] This figure is obtained as the difference between total cost (net of the cost of the counterfactual scenario with traditional meters) 12.115 £mil and the avoided cost for site visits 3.114 £mil, divided by the number of smart meters installed, i.e. 49 mil. Figures are taken from "Smart meter roll-out for the domestic and small and medium non-domestic sectors (GB), Impact Assessment, DECC 2013, page 73".

[34] In order to assess this figure, consider for example that the cost for site visits to collect meter reads, if the traditional system was carried on, would be of about £65 per meter over the entire period (2013 present value).

[35] However, over 30 to 40% of the benefits to be generated by the French smart metering system are expected to result from lower network losses (see "*Dossier d'évaluation de l'expérimentation Linky*", Commission de Régulation de l'Énergie, 2011, page 25).

[36] In the Italian cost-benefit analysis energy savings are not included among the benefits of gas smart metering.

replacement of inefficient appliances. In this respect, very different estimates of the impact of smart meters on energy demand are reported in international review studies and their actual value and persistence in time are still uncertain.

Furthermore, to the extent that energy savings result from appliance replacement, the (additional) cost of more efficient appliances should be accounted for in the cost-benefit analysis, which is not done in the assessments examined for this report. In GB, for example, each meter point is expected to generate 135£ net benefit, of which 132£ will come from lower consumption, i.e. as a result of either a change in consumption habits or replacement of existing appliances, whose cost is not accounted for in the cost-benefit assessment.

Finally, field trials typically assess the impact on energy demand of multiple simultaneous measures, including programs aiming to inform, engage, empower and motivate consumers. Therefore, it is difficult to single out the impact of smart meters and, more importantly, assess whether observed demand reductions would have resulted even without smart meters. In terms of cost-benefit analysis, that means that the counterfactual scenario should include the effects of measures for energy conservation that can be implemented without smart meters. For example, information and education programs might deliver changes in consumer's behaviour irrespective of smart meters.

The same observation applies to other aspects of the counterfactual scenarios in cost-benefit analyses. For example, issues related to estimate billing can be addressed by measures promoting meter self-reading by consumers. Consumer's financial management may be eased by appropriate pricing design. Further, introduction of smart meters should be assessed against a counterfactual scenario in which all opportunities to streamline supplier switching and optimise other industry processes have been fully exploited.

2.3.3 Observations

In the European debate on smart metering, mandatory roll-out – with compulsion on both the supply and demand side – is regarded somehow as a natural approach. Even in the Netherlands, where each consumer may refuse installation of a smart meter, this provision is not cast within a decision making approach seeking to bring consumers to reveal their valuation of smart metering and to use that information as a driver for the decision to implement smart metering.

There are obvious advantages in mandatory adoption of smart meters, including in particular full exploitation of scale economies and minimal need for involvement of consumers at the deployment stage.

However, once a public authority considers that there might be good reasons to intervene to displace competitive market forces and allocate resources differently from customer preferences, cost-benefit analyses become crucial to assess the investment's opportunity.

In this respect, the review of cost-benefit analyses carried out in some European countries shows that the evidence provided in support of large-scale deployment of smart meters is mixed. Large differences in observed results cannot be easily associated to social or economic differences among European countries. That suggests that some countries might be either selecting a suboptimal technological architecture or incorrectly assessing costs and benefits of smart metering. It is also worth bearing in mind that very limited spontaneous adoption of smart meters has been observed so far in the countries where this is possible.

The arguments in favour of mandatory roll-out featured in the policy debate, including the national cost-benefit analyses, are not as clear-cut as one would expect in the case of such an important policy decision which involves material costs for consumers.

Mandatory roll-out – from an economic perspective – is clearly not an issue in case smart metering costs are smaller than benefits directly obtained by the meter operator. In that case, smart meter deployment can take place without any additional cost for consumers. This was the case for example, in the Italian electricity sector, where distributors were authorised by the regulator to deploy smart meters under the condition that tariffs would not change. It also seems to be the approach currently followed in France.

Finally, it can be estimated that benefits delivered by smart meters in the water industry might be smaller than in the energy industry. The reasons are as follows: first, the value and possibility of short-term shifts of water demand are likely to be modest. Second, in a number of countries, political rather than efficiency considerations govern water pricing, in particular for residential users. These features limit the scope for efficiency gains via smart metering. Third, since vertically integrated (local) monopoly is the prevalent organisational arrangement for water supply, the scope for smart meters to streamline transactions among parties operating at the different stages of the value chain is limited.

However, in a multi-utility setting, the benefit of water smart metering might outweigh the incremental cost of implementing it, and therefore result in a net positive surplus to the overall cost-benefit assessment.

3. Smart metering technology

This chapter discusses high-level architectures for smart metering systems.

Section 3.1 presents the meter-related services. It also assesses the requirements those services place on the smart metering system's architecture. Section 3.2 describes the main functional elements of a smart metering system for residential and small-enterprise consumers. It also introduces a representation of that system's architecture. Section 3.3 characterises alternative smart metering architectures that are either already developed or discussed in Europe. Section 3.4 focuses on the architecture of the head-end of smart metering systems supporting meter data management. Finally, section 3.5 contains concluding remarks.

3.1 Smart metering features

This section characterises services and features delivered through smart meters and assesses what requirements their provision places on the smart metering infrastructure. In particular, communication requirements on the metering system, retail price policies and services supported are identified for each class.

3.1.1 Remote collection of (high-frequency) consumption data for billing purposes

The basic service provided by a smart metering system is the availability of high-frequency consumption data.

Older meters would not record any data; they could just make available the value of the total consumption register when reading took place. Storage capacity in the meter does not appear a constraint in current applications, from neither a technology nor a cost perspective. For example, current smart meters are generally able to memorise up to a few months of quarter-hour electricity consumption data. In addition, a variety of information on quality of service may be collected by current smart meters. These include, in addition to meter's diagnostics and service availability information, data on interruptions, voltage and harmonics for electricity, data on pressure and temperature for gas, detection of air in the pipelines, reverse flow and leakages at the consumer's premises for water.

Contrary to total consumption data, high-frequency consumption data cannot be manually read.[37] Earlier applications of automatic reading featured "walk-by" data collection: an operator would extract data from the meter through a hand-held device that had to be brought in close proximity to the metering unit. Walk-by collection evolved into "drive-by" collection: a van fitted with a wireless receiving station would drive through the neighbourhood collecting meter data. Current *advanced metering infrastructures (AMI)* feature two-way communication between meters and head-end system via a communication network.

Even if half-hourly consumption data are to be transferred from the meter to the head-end station, the bandwidth requirement to implement simple remote reading is modest for current communication technologies. In addition, since billing takes typically place monthly, few data transfer sessions are necessary, provided the meter has adequate storage capability.

Since metered data are used (only) to settle economic transactions well after physical delivery, the quality requirements on the communication channel for automatic meter reading are not high. In particular instantaneous availability of consumption data to the head-end system is not crucial for billing or similar "off-line" operations. Therefore, connection failure rates or latency times unacceptable for voice or critical data services[38] would generally be acceptable for transferring meter data for billing purposes.

Ex-post availability of high-frequency consumption data supports implementation of basically any retail price design, including *time-of-use pricing*, setting in advance different rates for consumption during different time-bands, and *spot pricing*, charging consumption, for example, in each hour at wholesale spot market clearing-price, or even the real-time price, for that hour. However, availability of high-frequency consumption data is not a sufficient condition to implement spot or real-time pricing; the other crucial condition is that consumers, or home-intelligence systems, be aware of the price relevant at each time. Alternative ways of conveying spot or real-time price information to consumers are discussed later in this chapter.

[37] Earlier systems for remote collection of metering data, known as *automated meter reading or AMR*, have been implemented for a long time in the US in the electricity industry *Metretek*, the first fully automated, commercially available remote meter reading and load management system, was launched in 1977.

[38] For example, commands sent by the electricity system operator to generating units providing regulation services or to substations' switches place much more demanding requirements on the communications system.

However, if spot or real-time pricing is implemented with a metering system based on one-way low-frequency data communication from the meters to the head-end system, consumers must have access to information on spot and real-time prices from a different source. For example, continuous information of spot power prices might be conveyed to consumers via the Internet.

While scheduled reading is necessary for regular billing, on-demand reading takes place when the customer moves out/in the premises or in case of supplier's switch.

The requirements placed on the metering system by billing consumed energy are not different from those related to metering of electricity exports from the customer's premises in case distributed generation or storage capacity is in place (if remote control of those facilities is not implemented).

3.1.2 Remote meter management and operation

Current technology makes remote management of some meter functions possible. Remote management functions include meter identification, tampering and fraud detection, meter battery status, meter malfunction, meter configuration and firmware upgrade.

Compared to simple automatic meter reading, discussed in the previous section, remote meter management places higher requirements on the communication infrastructure. Manageability as well as higher reliability and security of the communication channel are necessary for operations such as remote meter firmware updates.

An architecture supporting remote meter management allows implementation of additional functionalities such as, for example:

- remotely change the maximum load limit and remotely interrupt/reactivate supply;
- post messages to the consumer on the meter's display.

3.1.3 Price information to consumers through the metering system: case 1 – static price parameters

Greater consumer awareness of the cost and possibly environmental impact of consumption is among the key benefits expected from smart metering.

Smart meters capable of storing the consumer's price profile and processing consumption and price data, may be used to convey cost-related information to consumers.

Making cost available to the consumer via the meter entails communication between the meter and the head-end system in order to upload price parameters onto the meter. If price parameters are static, i.e. fixed for a relatively long period of time, communication requirements should be broadly similar to what is necessary to support remote meter management and operations, because price information would be sent to the meter only rarely.[39]

This functionality would not be highly time-sensitive, as price parameters could be uploaded any time before they become effective, provided the meter's registers are dimensioned to store multiple sets of price parameters.

The ability to store and process static price parameter is part of the set of minimum functional requirements for smart metering systems for electricity established by the Commission Recommendation of 9 March 2012 on preparation for the roll-out of smart metering systems (2012/148/EU).

An alternative way to convey cost information to consumers would leverage on the consumers' existing telecommunications channels and devices. In this approach, only consumption information would be extracted from the metering system and processed together with price information by a remote service provider[40] or by the customer's home-intelligence system.

In this scenario the service provider or the consumer's device would:

- collect consumption information from the meter;
- retrieve information on the relevant price profile from the Internet;
- based on this data, calculate cost;
- (in case calculation is performed at the service provider's back-end) present the results to consumer over the Internet.

Compared to the solution based on the meter, this solution would:

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[39] This is the case, for example, of time-of-use prices with unit charges for each time band set annually.

[40] In this case metered consumption data would be backhauled to the service provider.

- make the communication flow on the pricing profile from the metering head-end system to the meter unnecessary;
- make computational intelligence inside the meter unnecessary;
- be more flexible, because software installed in the consumers' devices would be easily upgradable in order to manage new and arbitrarily complex pricing structures.

3.1.4 Remote control of domestic appliances and distributed generators

The smart metering system may be used to convey commands to electric appliances, included distributed generators, at the consumer's premises. This opens to door to a range of services provided on consumer devices, for instance, on the basis of information gathered via smart metering.

This functionality supports a demand response model in which the consumer grants (some) control over his appliances to a load aggregator in exchange for compensation; typically such role would be taken on by the retailer and the flexible consumer would pay lower electricity prices. Within the agreed limits, the supplier would then control the consumer's load by sending commands to the consumer's appliances via the smart metering communication infrastructure. Earlier implementations took place for example in the US, where customers' water boilers would be turned on and off by the utility supplier as a way to shape aggregate load. In Europe, this approach is implemented extensively in the Czech Republic, where ripple control receivers are active for 25% of domestic electricity consumers.

The same mechanism can be implemented to control energy exports to the distribution network by distributed generators, such as photovoltaic panels, or energy storages like electric vehicles' batteries.

The possibility to remotely curtail distributed generators could turn out useful also to distribution system operators in emergency conditions, in case price-based flexibility be less than what is necessary to maintain security conditions.

The German, British and Dutch smart metering projects include among the smart metering system requirements the possibility for the distributor or a third party to send activation/deactivation signals to consumer's appliances and micro-generators.[41]

Sending commands to consumers' appliances via the smart metering infrastructure requires high rates of service availability of the metering communication system.

Short-term demand price-response, relevant in particular for electricity, requires:

- processing real-time or near-real time prices;
- automatic control of consumer's electric appliances, including on-site generators.

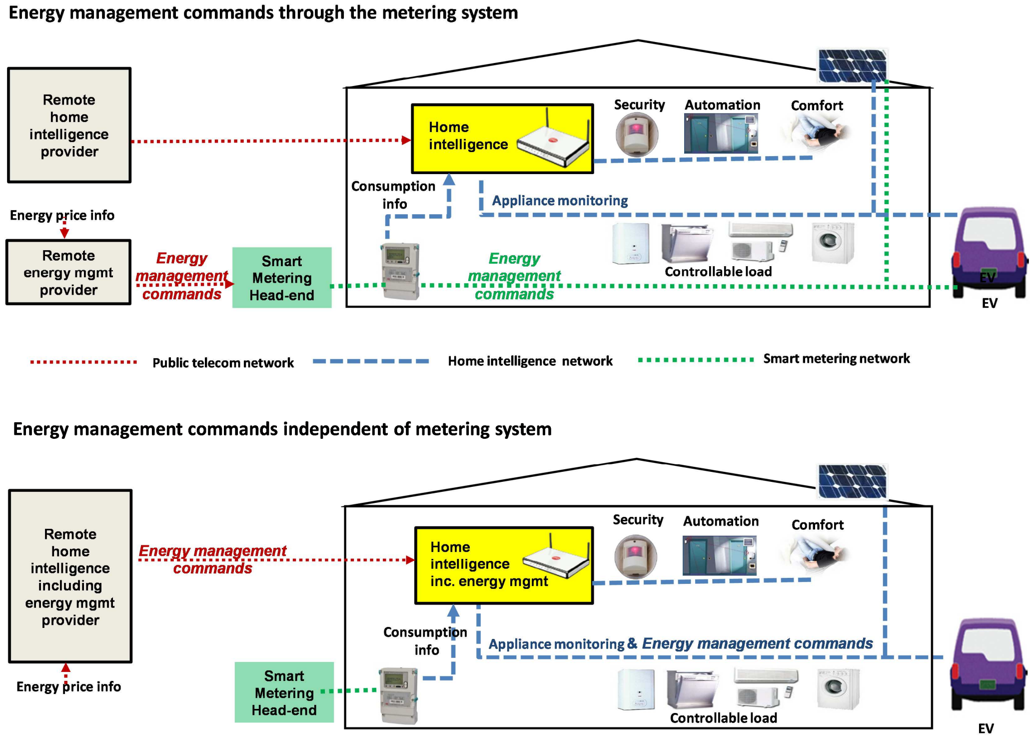
The basic design choice for a smart metering system, in this respect, is whether the metering infrastructure should provide functionalities supporting these features, or whether these features should be independently implemented. As illustrated later in this chapter, some smart metering system architectures allow conveying to the consumer's appliances control signals originated by remote load managers, acting as aggregators of flexible loads. In this approach, communication between meters and the metering head-end station is crucial,[42] since the metering communication infrastructure is used to transmit load control signals.

An alternative approach relies on a separate infrastructure to transmit load control information to consumer's appliances. In this approach, a device implementing home-intelligence, independent of the metering system, receives load control signals and implements load management actions. The meter simply provides information on current consumption, through a local interface between meter and such device. Such solution makes the requirement for (fast) two-way communication between meter and the metering head-end station unnecessary. Figure 3 illustrates the two approaches.

[41] However, such feature does not appear to be part of the set of minimum functional requirements for smart metering systems for electricity established by the Commission recommendation 9 March 2012 on preparation for the roll-out of smart metering systems (2012/148/EU).

[42] Unless otherwise indicated, it is assumed that load control signals conveyed via the smart metering system are channeled through the head-end station. In an alternative implementation, the load manager can send signals directly to the meter; in this case multiple parties would be entitled to access to the meter at the same time.

Figure 3 - Alternative approaches to load control



The former approach guarantees integration between the metering system and the load management system. Further, it allows implementing the same level of security in both areas.

The latter approach has the following advantages. Firstly, it allows greater flexibility in design and implementation of load management services. For example, the meter-independent home-intelligence system might supply multiple services, including load management, home security, remote appliance monitoring and maintenance, etc.

Secondly, a load management system independent of the metering system maximises the scope for competitive provision of services. In particular, the innovation potential of competitive suppliers of load management and other services based on home-intelligence is not constrained by the design of the metering system. For instance, different home-automation systems may deliver different services or may split intelligence between the remote and the local equipment differently. Moreover, independent load management systems may flexibly leverage on communication channels already active at the consumer’s home.

Thirdly, integration of load management features in the metering system may result in unfair cost allocation, in case consumers unwilling to buy load management services end up bearing part of the additional cost necessary to implement smart metering infrastructure supporting load management.

3.1.5 Price information to consumers through the metering system: case 2 – dynamic price parameters

The previous section has described a demand response model based on remote control of consumer's appliances by a load manager.

In the alternative model, consumption/production decisions are made by the consumer or by some equipment under the consumer's control. In this approach, implementing short-notice demand response to price requires that retail prices faced by consumers change continuously following wholesale spot or real-time prices. That requires that consumer's home-automation systems receive price signals on a continuous basis, for example every quarter of an hour.

This information flow on prices could be conveyed through the metering system meter. However, we are not aware of any projects implementing continuous transmission of real-time electricity prices to the consumer's premises via the smart metering system.[43]

Efficiency of conveying spot or real-time price information through the metering systems, at least in a plausible technological scenario, is questionable. In particular, eliciting short-term demand response will require that some form of home-automation be implemented at the consumer's premises. In a plausible technological scenario, the home-automation system would be managed by a device different from the meter. This device would command home appliances, including distributed generators and electric vehicles, based on the consumer's preferences and on the spot or real-time price for electricity. In addition, it is fair to assume that consumers engaging in short-time electricity demand response are sophisticated enough to be endowed with one or more Internet access channels at their premises. Under those assumptions on the technological scenario, conveying spot or real-time price information through the metering system might be useless, since

[43] The European Commission Recommendation of 9 March 2012 on preparation for the roll-out of smart metering systems (2012/148/EU), mandates ability of smart meters to store and process – generically – tariff parameters.

alternative communication channels would be available and home-automation intelligence would be provided by specialised equipment. The interaction between the home-automation system and the meter would then be limited to extracting instantaneous consumption data from the meter. This model is currently being implemented, for example, in Italy.

3.1.6 Prepayment

Two broad models for implementation of prepayment supply are envisaged, each placing different requirements on the metering system.

Prepayment requires that information on current consumption, applicable pricing option and consumer credit be processed together, in order to trigger supply interruption and activation. All this information may be processed either by specially designed meters or by the head-end system. The relevant design choice is then between distributing intelligence in the field, i.e. inside prepayment meters, and frequent communication between standard remotely controlled meters and the head-end system.

A first approach is based on relatively sophisticated meters and little communication with the metering head-end system. The consumer uploads credit to the meter. The meter compares the consumer's credit and expenditure on a continuous basis, based on metered consumption and price data stored in the meter. When the consumer's credit is exceeded, supply is interrupted or limited, until credit is replenished. In this approach, prepayment does not cause any additional information flow between meter and metering head-end system, since the intelligence supporting prepayment resides in the meter.

The alternative approach places intelligence supporting prepayment at the head-end level. The consumer uploads credit to the head-end system, possibly via phone or the Internet, and the meter regularly (e.g. daily) sends consumption data to the head-end system. The head-end system compares consumer's credit and expenditure and, once credit is over, sends to the meter a command limiting or interrupting supply. In this approach, prepayment does not require a special meter, but it makes regular – in our example, daily – communication between meter and head-end station necessary.

3.1.7 Observations

Traditional meters for small consumers were used exclusively to collect consumption data for billing purposes. The same objective can be achieved through relatively simple smart metering architectures. Even a slow communication channel from the meter to a head-end system can transmit, for example monthly, even high-frequency consumption data, which can be cheaply stored in the meter until transmitted.

Reliability requirements on the communication channel are not overly demanding, since billing takes place long after consumption takes place. There are therefore no time constraints to repeating transmission sessions in case of failures. Such relatively simple smart metering design can support any form of static retail pricing option.

More advanced features, like remote meter management or load and local generation control, place heavier requirements on the metering communication infrastructure.

Integration of smart metering and home-automation systems can follow two broad approaches. First, the smart metering system may just provide consumption data, while an independent system elaborates information on prices, consumption and consumer preferences; management of electrical appliances also takes place with no involvement of the metering system. This approach is compatible with load management intelligence either residing in consumers’ equipment or being centralised in a remote load management system.

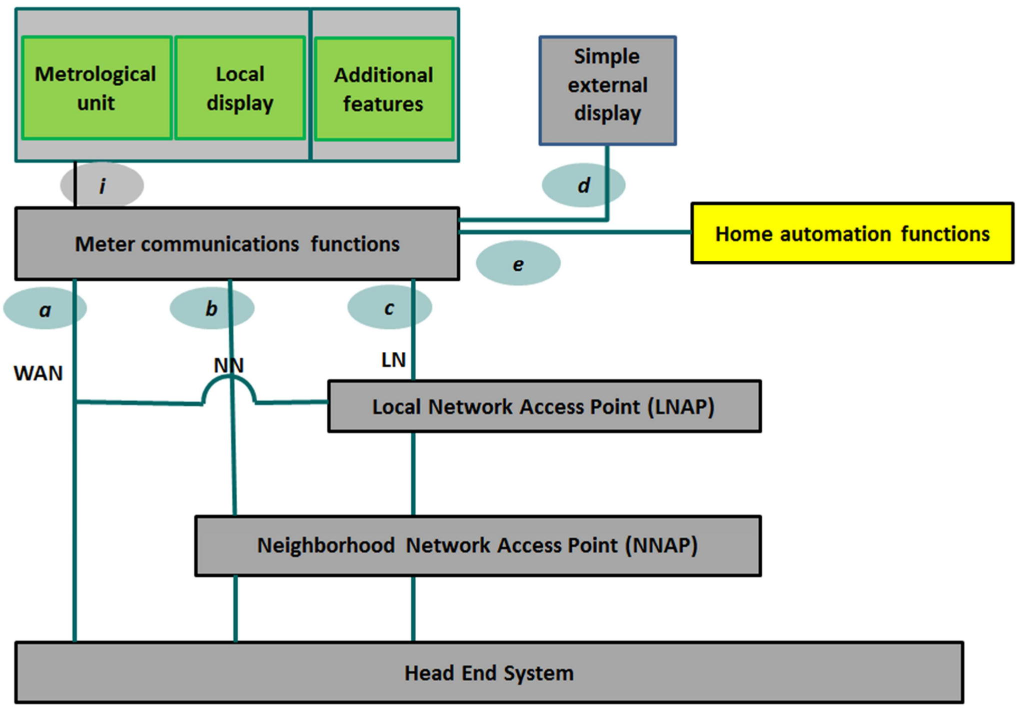
Alternatively, the smart metering communication infrastructure is used to convey load control signals, issued by load managers. This model is consistent with remote load management intelligence.

Alternative models may have different implications for the home-automation industry. For example “consumer-grade” hubs implementing load management intelligence are not necessary if centralised remote load control is implemented. As a consequence, in a model based on centralised remote control, there might be little room for producers of electrical appliances to integrate in the supply of load management intelligence. However, assessing these implications is beyond the purpose of this research.

3.2 A reference model for smart metering systems

The following figure illustrates functional reference architectures for so called *advanced metering infrastructure (AMI)*. Those refer to infrastructures which allow two-way communications between the *head-end system* and the meters and may be linked to in-house devices, including electrical appliances and distributed generators. The picture is adapted from CEN/CENELEC/ETSI 2011.[44]

Figure 4 - Reference model for Smart metering system architecture



The *metrological unit* is the part of the metering system that measures electricity, gas, heat or water flow. A display may or may not be physically assembled together with the metrological unit.

Additional features include, for example, a remotely operated switch that allows limiting maximum power withdrawal or a valve that enables remote cut-off of gas supply.

The metrological unit interacts with the meter's *communication functions*. These can be implemented via hardware placed inside the same case as the metrological unit (and possibly a local display), or via a separate piece of hardware, connected to the metrological unit through

[44] Functional reference architecture for communications in smart metering systems CEN/CLC/ETSI/FprTR 50572.

interface *i*. The latter solution may be cost effective in case a single communication unit is used to channel data supplied by multiple metrological units, for example for gas, water and electricity, installed in the same building. Where communications between multiple meters take place through a single device, such device typically performs further functions, such as data storage, data aggregation and enforcement of access rights to meter data.

Where not otherwise stated, *meter* refers to the piece of hardware implementing the metrological functions. Depending on the implementation, then, the *meter* may perform further functions, including in particular communication functions.

The meter's communication functions include one or more of the following interfaces:

a) the metrological unit may interact with the metering head-end system via the wide-area-network (WAN), which is implemented via existing public telecommunications infrastructure. That would be the case, for example, if cellular modems were used to transmit metering data from the meter to the head-end system. Several network options are available on the market for WAN communication, including GSM/GPRS, UMTS, LTE and DSL. Assessing the merits of alternative solutions is, however, beyond the purpose of this report;
b) the metrological unit may interact with the metering head-end system via a neighbourhood network. That would be the case, for example, if metering data were radio transmitted from the meters to data concentrators, each serving several premises. Coverage of up to 1-2 km is typical of neighbourhood networks. Besides connecting meters and the head-end system, neighbourhood area architectures may provide additional services, typically smart-city services;
c) the metrological unit may interact with the metering head-end system via a local area network, connecting in house/in building devices, a *home area network*. That happens, for example, if communication between the meter and the head-end tool place through a building electronic system. Additional services that can be provided by this architecture are typically home-automation services, ranging from home surveillance to energy management. When necessary, these services will typically interface with the smart

metering system at the local area network level. Coverage of up to several meters is typical of home area networks;

d) basic visual access to metered data may be implemented via a simple external display connected to the metering unit. An external display presents advantages compared to a display attached to the metrological unit. First, the external display may be placed in a convenient location for the consumer. Second, the external display may be mains-powered, thus reducing battery consumption in battery powered meters. The external display does not necessarily have to be a specialised piece of equipment; on the contrary meter information could be visualised through one of the several devices owned by the consumer, such as a personal or tablet computer or a smartphone. This solution would be cheaper, since it would not require an additional piece of hardware, and therefore, it could possibly be more attractive for consumers;

e) *e*: access to meter data may be implemented through an interface implementing a data path between the metering unit and external devices. In the above picture this interface is represented to connect the meter with the home-automation system. Where not otherwise stated, devices controlling distributed generation at the customer's premises as well as the governing charge and discharge of electric vehicles batteries are included in the concept of home-automation system.

Since different communication solutions entail different power consumption, the most effective option may be different for battery-powered and mains-powered meters.

The *head-end system* is the infrastructure where meter data is collected, validated, stored and made available to the entitled parties. Some head-end functions may be performed at the neighbourhood network level provided the necessary intelligence is implemented at that level. For example, electricity distributors might directly operate concentrators to send connection/disconnection signals to meters and flexible load devices, rather than channelling commands through the head-end system. In the model being developed for Germany, head-end functions are implemented at the LNAP level.

3.3 Smart metering architectures

A range of alternative implementations of the functional architecture presented in section 2.2 can be conceived. On the one hand, devices and communication interfaces can be configured in different combinations to provide the same services. On the other hand, as pointed out earlier in this report, certain services might be provided by means other than the metering system.

In this section, different solutions implemented or discussed in Europe are reviewed. Section 3.3.1 focuses on the solution implemented in Italy's electricity sector, based on power-line transmission of meter data. Section 3.3.2 describes a solution based on an ad-hoc neighbour-area radio-based network, proposed for example for gas metering in France and Italy. Section 3.3.3 presents an approach based on a local area network at the consumer's premises, proposed for multi-utility metering in Great Britain and Germany. Finally, section 3.3.4 discusses alternative arrangements for administration and storage of meter data and their interaction with industry processes.

3.3.1 Power line communication carrier: Italy, France (forthcoming), Norway, Sweden and the Netherlands

The world's largest smart meter deployment was undertaken by Enel, the largest electricity distributor in Italy serving more than 30 million customers. Between 2000 and 2005 smart meters were deployed across the entire customer base. ERDF, the French electricity distributor, plans to implement the same metering architecture to 35 million consumers between 2013 and 2018.[45] Vattenfall has implemented an automated meter reading solution based on power line communication carrier for 600,000 customers in Sweden.[46]

Figure 5 illustrates the architecture of a smart metering system based on power line communication carrier technology. The metrological unit, a simple display, a remotely controlled switch and the communication device are hosted in the same case.[47] Bidirectional communication between the meter and the head-end system is implemented. Data are carried between meters and data concentrators located in the electricity substations (about 500,000 in Italy) on the low

[45] Le compteur communicant Linky d'ERDF: Une expérimentation réussie – ErdF.
[46] Telvent, Smart metering solution in Sweden.
[47] Placing the metrological unit, display, switch and communication device in the same case is a common to all applications that were surveyed.

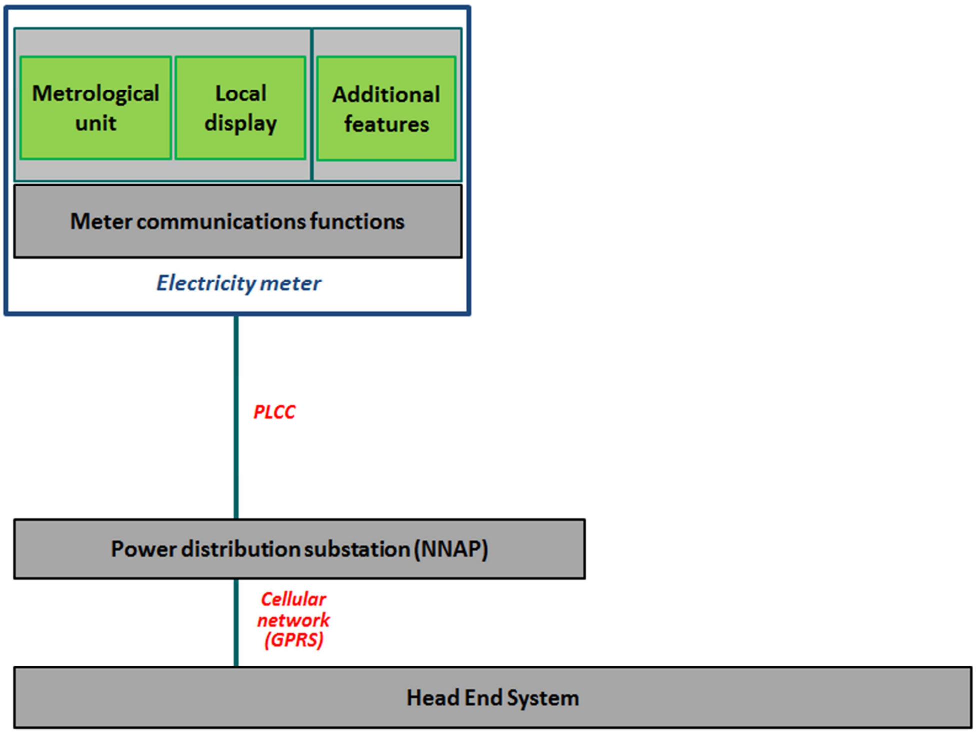
voltage lines, using power line communication carrier technology (or PLCC). Data concentrators communicate with the head-end system through the conventional mobile network.

The system allows collecting data on the consumer's monthly total consumption during each of four time-bands. In addition, tampering and service outages are detected.

Meters can be remotely controlled, in particular to activate/shut-down supply and change the maximum power that can be withdrawn at any time.[48]

Through the meter's display, the consumer may access information on current withdrawal, consumption since the last reading in each time-band and maximum allowed instantaneous withdrawal.

Figure 5 - Smart metering system architecture using power line communication carrier technology



[48] The maximum withdrawal allowed is reduced to 0.5 kW for consumers not paying their bills. This measure is less destructive, but broadly as effective as full disconnection.

In terms of the service classification discussed in section 2.2, the current Italian smart metering system allows:

- remote collection of consumption data for billing purposes, with limitations on the frequency of the consumption data collected;
- remote meter management.

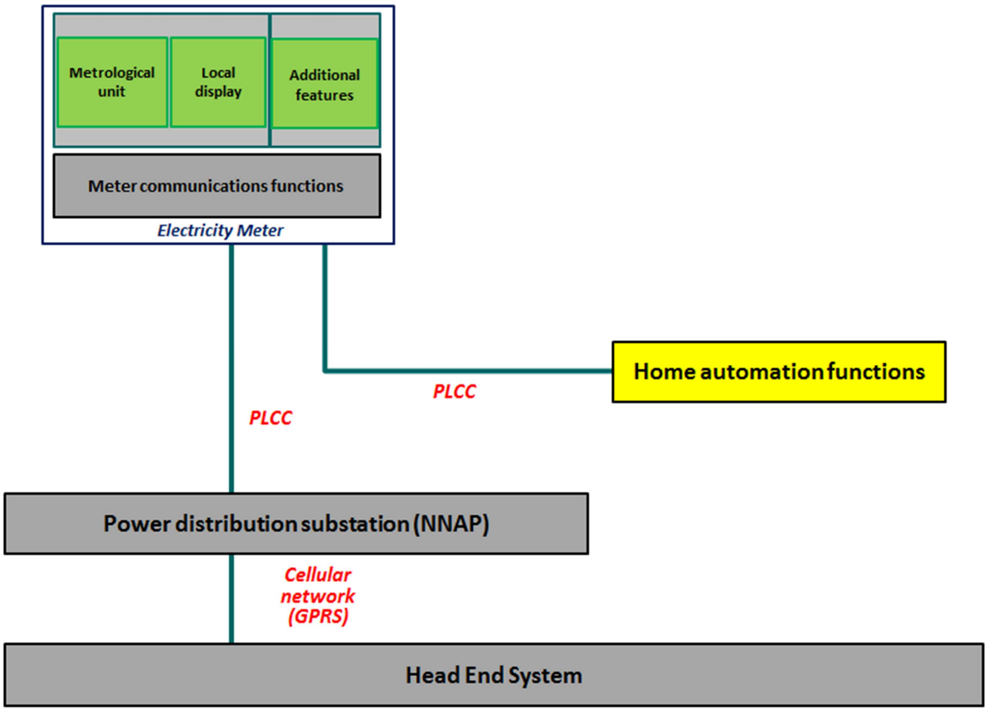
However, it does not allow to:

- send price or instantaneous consumption information to the consumer;
- implement prepayment;
- remotely control the consumer's electric appliances.

Consumers have access to current consumption information through the meter's display and to historic meter readings via the head-end system, as all other parties entitled to that information. However, in the current implementation, consumers cannot access data on current electricity withdrawal on a continuous basis, for example on an in-house display. For that purpose an additional interface between the (electricity) meter and the consumer's home-automation system, which an in-house display is the simplest form of, is required. Such interface could be implemented, for example through PLCC or through short distance radio transmission.

An additional feature being developed in Italy is a local interface between the meter and the consumer's home-automation system: data on instantaneous consumption will be fed by meter into the home-automation system via PLCC. This is illustrated in the following figure.

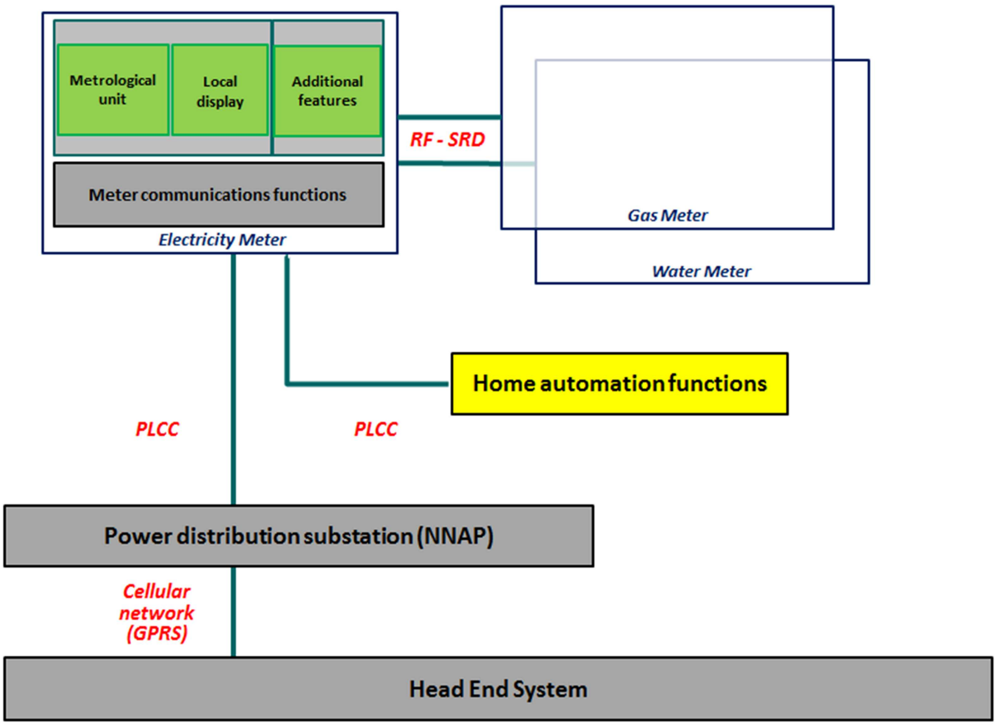
Figure 6 - Local interface between meter and home-automation system



A multi-utility application of power-line communication technology is being pursued in Norway[49] and the Netherlands.[50] This solution, illustrated in Figure 7, would use the electricity meter's PLCC channel to route gas and water meter data. Short-range wireless communication would be implemented between the electricity meter, at the one side, and the gas and water meters, at the other side. The electricity meter would then transmit over the existing PLCC infrastructure data received from gas and water meters to the head-end system, which would forward them to the designated parties.

[49] Hanne Saele, *Requirement of smart metering architecture and smart metering in Norway*, SINTEF Energy Research, 17 and 18 April 2013, Stockholm.
[50] Netbeeher Netherland, *Dutch Smart Meter Requirements, Release Notes V4.0.5*, Netheer Nederland, May 15 2012, requires that the electricity meter, connected to a data concentrator via PLCC, be fitted with a 868 MHz M-Bus wireless port to connect with gas and water meters.

Figure 7 - Multi-utility application of power line communication technology



3.3.2 Radio-based neighbourhood network: French and Italian gas metering systems

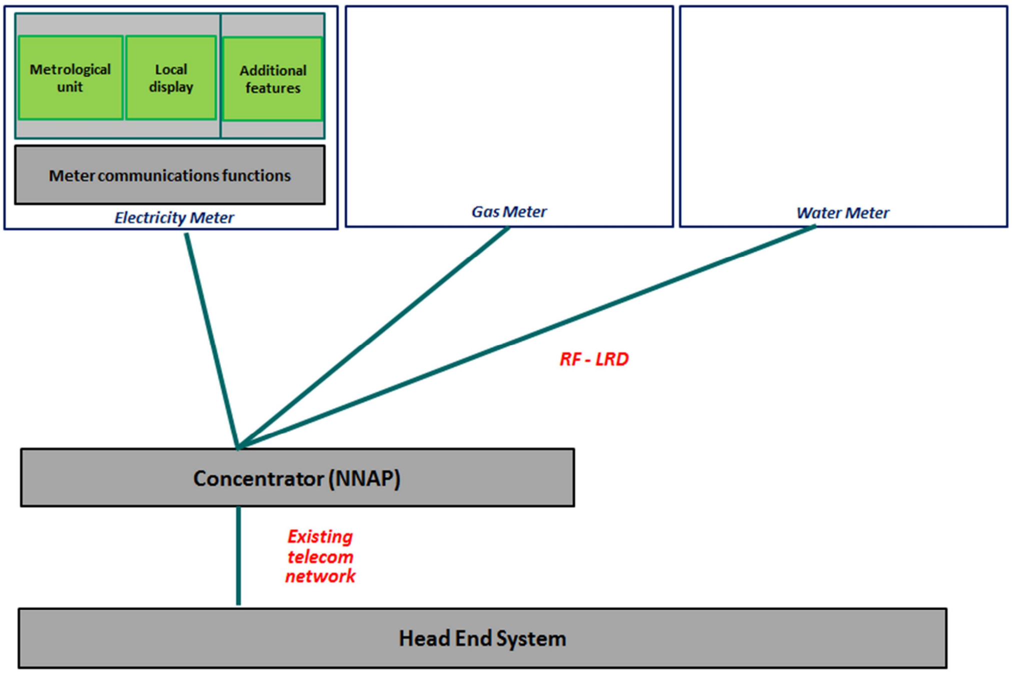
The following figure illustrates a smart metering system architecture based on radio transmission from the meters to concentrators located up to 1-2 kilometres. For example GrDF's project for a gas smart metering system in France foresees installation of 20,000 concentrators supporting 11 million meters.[51] Pilot projects for gas and water metering based on this architecture are currently being selected in Italy.

Concentrators, which need to be mains-powered, may be located inside electricity substations, mobile network radio base stations or even on street-light poles. Concentrators communicate with the head-end system via existing mobile or land-line networks. Communication between meters

[51] Smart Gas Metering in France, GrDF – Drochon, Desandre.

and concentrators takes place via radio.[52] Repeaters would be deployed in areas where the meters' transmission does not reach a concentrator.

Figure 8 - Smart metering system architecture using radio transmission



A radio-based system with neighbourhood-scale concentrators appears to be well suited to delivering the same set of services made available by PLCC-based solutions. These are in particular services requiring batch data flows at predetermined times or on call – such as monthly meter reading of high-frequency consumption data – and limited information flow towards the meter – for example remote service interruption and restoration, on call reading in case of supplier. Services requiring continuous information flow from the head-end system to the meters appear to be more difficult to support by this architecture.

Consumers would have access to current consumption information through the meter's display, if present, and to meter readings via the head-end system, like all other parties entitled to that information. However, in its basic version, this solution does not allow to make data on current

[52] Both in Italy and France communication between metrological units and the concentrators will use Wireless M-bus technology at 169 MHZ (see Appendix 1)

electricity withdrawal available to consumers on a continuous basis, for example on an in-house display. For that purpose an additional interface between the meter and the consumer's home-automation system, which an in-house display is the simplest form of, is required. Such interface could be implemented, for example through a local port, short-range radio transmission technologies or, for electricity meters only, PLCC technology.[53]

Radio-based systems with neighbourhood-scale concentrators do not appear to be suited to support applications entailing sending information to the consumer on a continuous basis or to support smart-network applications such as remote control of micro-generators or load.[54]

However, a neighbourhood-level network of concentrators may be used to provide further services. These are typically "smart city services", including control systems for street lights, parking spaces, waste containers and surveillance.

3.3.3 Home area network solutions: Great Britain and Germany

Figure 9 illustrates a smart metering architecture in which the interface between metrological units and the wide area network is implemented by a device, the smart meter gateway or communication hub, located at the consumer's premises.

The smart meter gateway is the centre of the metrological network,[55] i.e. the communication links between the metrological units, and of the home area network, which includes certain consumer devices. The smart meter gateway implements only one-way communication (of metered data) between the metrological network and the home area network.

Consumer's devices connected to the smart metering gateway, the "controllable local systems",[56] may communicate with each other and with remote entities via the wide area network through the smart meter gateway. In particular, they can receive remote activation/deactivation commands.

[53] Continuous data transmission may be unfeasible with battery powered meters. Implementing a local port is still under investigation for smart gas meters in France.
[54] Contrary to systems where radio communication is used to cover only short distances, like those discussed in the next section.
[55] In the UK terminology the metrological units and the consumer's appliances connecting to the smart metering gateway are referred to as "home area network". The German approach is followed here. It distinguishes between the metrological units (the metrological network) and other appliances connecting to the smart meter gateway (the home area network). This distinction emphasizes segregation of the metrological units from other appliances. For example, devices belonging to the home area network can also be connected to the Internet, while metrological units cannot.
[56] Or Consumer Access Devices, in the UK jargon.

Controllable local systems may include white goods, electric vehicles and distributed micro-generators, for example photovoltaic units or micro combined heat and power systems. Third parties interacting with controllable local systems may be load-management providers or the distributor, for example, to address network security issues by modifying the distributed generators' net injections into the grid.

In Figure 9 the box on home-automation functions is meant to represent any consumer device interacting with the metering system through the smart metering gateway, including in-house displays, consumer access devices and controllable local systems.

The smart metering gateway bridges the metrological network and the home area network with the wide area network.[57] Finally the smart metering gateway performs additional functions, such as data storage and processing, sending power outage and restoration recording and notification. The role of the gateway is being discussed in the next subsection.

The main advantage of placing at the consumer's premises the interface between the Wide Area Network and metrological units is the bandwidth of the resulting communication system. This happens because of the availability of protocols for short distance radio communication which can deliver high bandwidth and efficient sharing of the communication channel among multiple devices (see Appendix 1).[58]

This assessment is in line with the British government's statement that frequencies typically used to link meters and concentrators in a neighbourhood-network scenario like the one discussed in the previous section (169 MHz and 433 MHz), are considered unlikely to have sufficient bandwidth to meet the needs in terms of range of functions and frequency of messaging.[59]

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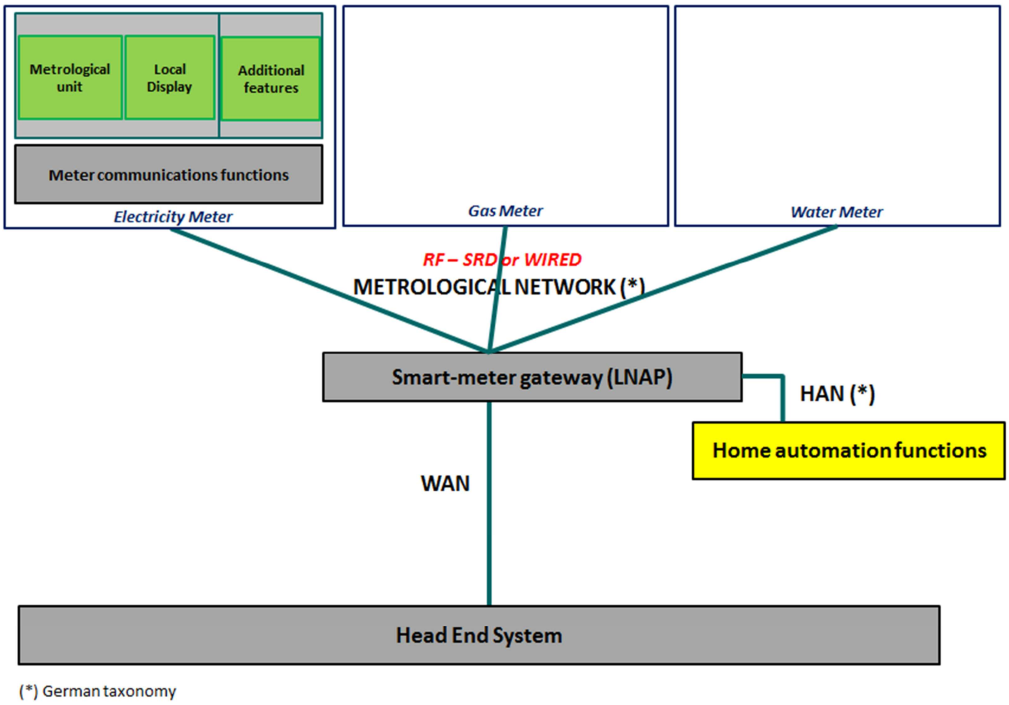
[57] In the German solution, wireless communication between metrological units and the smart meter gateway are set to use Wireless M-bus technology at 868 MHz and wire communication the TCP/IP protocol stack on a RS 485 physical infrastructure. An Ethernet connection is foreseen between the smart meter gateway and external displays or personal computers. The interface between controllable local systems and the smart meter gateway has not yet been standardised.
In Great Britain, ZigBee Smart Energy Profile and DLMS (Device Language Message Specification) at 2.4 GHz (and 868 MHz when available) are foreseen for communication between metrological units and the Communication hub, the latter technology being more suitable for battery powered gas and water meters.

[58] Bandwidth availability on the Wide Area Network is not an issue, since it is far above any requirements of the smart metering system.

[59] Department of Energy and Climate Change (DECC) - UK Government, *Smart Metering Implementation Programme. Consultation on the second version of the Smart Metering Equipment Technical Specifications*, 13 August 2012.

Figure 9 - Smart metering system architecture using a gateway (communication hub)



3.3.4 Meter data administration

This section presents alternative meter data administration models. Those differ in where metering data are stored and, more importantly, where access rights to those data are enforced. In the centralised model meter, data are stored in a central repository. Each party entitled to access, or responsible for supplying meter data interacts (only) with the central repository. In terms of the figures of the previous subsections, one may think of the head-end system as the place where data are accessed by entitled data users. In other terms, there is a single repository (being it physical or logical) where all consumption and production meter data relevant for transactions are collected.

The scope of a central repository is generally seen as wider than managing meter data. In particular, a central repository may simplify industry processes involving communication among multiple parties, by reducing the number of transactions. Consider for example electricity supplier switching. When a consumer changes supplier, information needs to be exchanged among several parties, including at least the following:[60]

- The former supplier needs to be notified that the consumer terminated the contract; it also needs to know the consumer's metered withdrawal up to the switch date, in order to issue the final invoice;
- The distribution company and the transmission company need to be notified that a different supplier is to be invoiced distribution and transmission services that are provided to the consumer's withdrawal point;
- The entity responsible for imbalance settlement, typically the system operator, needs to be notified that the consumer has moved to a different balancing group.

If a central switching agent is implemented, the consumer's move may take place without any direct data transfer between the former and the new suppliers.

Furthermore, with a central repository imbalance, settlement and invoicing of transmission and distribution services to load serving entities are based on meter data provided by the central repository. This virtually eliminates any disputes on electricity volumes.

In a decentralised model, data are more dispersed. This is the case, for example, in case responsibility for collecting and storing meter data for different consumers is placed on different parties. For example, in case distributors are responsible for metering, each consumer's information is stored by the distributor, which enforces the other parties' rights to access meter data. Where, as in the United Kingdom, the supplier is responsible for metering, each supplier is responsible for storing and sharing its clients' information with parties entitled to access them.

The architecture being developed in Germany (also) supports an extreme form of data decentralisation. From the physical perspective, meter data are stored at the consumer's premises

[60] In practice, each of those notifications requires multiple messages among involved parties, including acknowledgments and confirmations.

by the smart metering gateway.[61] Each data user receives the data set he or she is entitled to access from the gateway.

When decentralised data storage is implemented, communications among parties carrying out transactions in the industry are typically subject to some form of coordination. In several European countries, a communication agent defines standard messages to be exchanged between the information systems of the parties involved in each process and runs an information technology platform through which messages are sent. The communication agent does not store any customer-related data. However, it keeps track of each information exchange carried out through the platform, which allows assessing, in case of disputes, each user's responsibility or compliance to industry rules.

Norway and Denmark implement centralised consumer data storage. Italy is heading in the same direction. All other European countries have opted for decentralised data storage, with communication agents implementing industry processes.

3.4 Smart metering services

The analysis of smart metering technology points at two broad sets of services differing in terms of feasible and most suitable forms of organisation.[62] The first set, which we term "meter availability" services, consists in making the meter's functionality available to the parties in charge of (or entitled to) collect data and send load management signals, if this functionality is available.

Delivering meter availability services entails mainly installation and maintenance of the meter at the consumer's premises.

Some similarities exist between meter availability and local loop services in telecommunications networks. First, supply of both services entails large and sunk fixed cost. In particular, when a working meter is in place, duplicating or replacing it is very costly: replacement is expensive compared to total cost of service. Similarly, roll-out costs for the last mile in telecommunications

[61] This solution avoids centralisation of meter data in the data manager's systems, which might be desirable from the data protection perspective. Data protection issues are discussed in chapter 5.
[62] In section 4.4, these services are related to the notion of relevant market, which serves as a basis for the competitive analysis.

networks are high and generally duplication of local loop is inefficient.[63] Second, both local loop and meter functionalities are suitable for third party access. In particular, aside from the metrological unit, the meter is basically a data storage and communication device meant to be remotely operated.

The second group of metering services, which we term "data management", consists in:

- collecting meter data and making them available to entitled parties in the correct format and timing;
- administering the rights of third parties to send signals via the metering infrastructure in order to remotely interrupt/resume energy flow, manage consumer's load or control embedded generation.[64]

Delivering meter management service requires installation, maintenance and operation of a head-end IT infrastructure and procurement of telecommunications channels from local data concentrators to the head-end system.

We use "meter availability" and "data management" as logical categories in order to group homogenous activities in terms of feasible and desirable form of organisation. However, the content of each category may be slightly different for different technological architectures.

For example, while in some implementations meter data are stored in the data manager's database, in the German model meter data are transferred to data users directly from the local concentrator. In this approach no centralised storage of meter data takes place and the set of activities which we refer to as "data management" does not include any information handling. The data manager reduces to a "gateway administrator" that runs the registration system of users allowed to receive data and programs local concentrators to send meter data to entitled parties.

An alternative approach is followed in Italy for electricity, where distributors provide meter availability services and a central data provider validates and enforces access rights to meter data.

[63] However, in this respect, a potentially relevant difference between meter availability and local loop telecommunications services is that only in telecommunications legacy networks are in place.

[64] Installation and management of data concentrators cannot be naturally associated to either meter availability or data management service. In some situations, it might be more efficient for concentrators to be operated by the meter availability supplier, while in others it might be efficient that concentrators be operated by the data management supplier. This issue is being discussed later in the report.

In this case the "data manager" 's role is skewed towards data handling, since meters are queried by distributors to collect data, which is first stored by in the distributors' systems and then sent to the data manager.

The assumption that meter availability and data management services can be separated is based on our understanding of the technical features of each group of activities and on implementations that are being developed in some European countries. We address at a later stage the merits of alternative institutional arrangements, including the possibility that meter availability and data management services be provided by different parties.

3.5 Remarks

Different technological options for smart metering systems are still being considered or have been selected in different countries. Therefore, the analysis of the technological choices being made in different countries does not naturally indicate that any particular solution is superior to the others.

This may be the result of specific national or regional features affecting the relative merits of alternative solutions. For example, the opportunity to use smart metering infrastructures to supply other smart-city services may be different in different places. Based on available information, however, such country-specific effects cannot be assessed.

Furthermore, path-dependency may become relevant to the selection of the most suitable architecture for smart metering. In some countries, for example, stand-alone electricity smart metering systems may already be in place when the opportunity to set up a gas or water smart metering system is considered. It might then turn out that a multi-utility metering architecture is not worth setting up, while such multi-utility approach would have been the best choice had the smart metering system for electricity not been in place.

4. Smart metering organisation and institutional framework

This chapter discusses the relative merits of various organisational models for metering activities and assesses their consistency with the European institutional framework.

Section 4.1 investigates whether developments in metering technology and the unbundling of electricity and gas supply justify rethinking the traditional industry-specific regulated monopoly model, in which each distribution network operator is responsible for measuring withdrawals through its network's delivery points. Section 4.2 presents alternative organisational models of supply of metering services. Section 4.3 investigates relative merits of competition in and regulation of supply of metering services. Section 4.4 discusses legal and regulatory constraints on metering activities.

Finally, Section 4.5 develops a set of alternative scenarios, characterised by different regulatory and organisation frameworks for meter availability and data management services. In Appendix 2, these scenarios are compared with those considered by the European Commission's working group on smart grids.

Rights and responsibilities to deliver metering services can and are generally assigned to parties different from those who actually implement service or provide important inputs. Transfer of implementation responsibilities commonly occurs in all industries to minimise cost, but it may also result from technological constraints or from pre-existing organisational models. This chapter focuses on assessing alternative allocations of rights and responsibilities related to overall metering service delivery rather than on implementation.

4.1 Technology, supply liberalisation and organisation of the metering business

Prior to liberalisation, metering activities were regarded as part of the monopoly supply business. As part of a regulated business, metering costs were passed on to consumers via regulated tariffs. Quality of service, mainly in terms of measurement precision and frequency of meter readings, was also subject to regulation. With vertical unbundling of electricity and gas supply, in most countries metering activities have been considered as embedded in the distribution business, a regulated monopoly. This model is currently prevalent in Europe.

This section investigates the rationale for assigning meter responsibilities to distributors. It also assesses the case for that model in light of developments in metering technology as well as in the organisation of energy markets.

Assigning meter responsibility to distributors is coherent with some features of traditional metering technology and organisation of energy markets.

First, as far as the organisation of the energy supply business is concerned, the allocation of monopoly on metering to vertically integrated utilities is consistent with those companies acting (also) as retailers and distributors. In that context the utility was the only user of meter data, besides consumers. Further, within traditional integrated utilities, unified management of “downstream” activities, including distribution, metering and retail was common. Presumably, the main drivers for the selection of this organisational model were that meters were seen as a network component from a technical perspective and that retail consisted mainly in customer management.

Second, traditional meters do not record the consumer’s withdrawal in each time interval, but only total withdrawal over a long time period. In some cases, only total consumption since the time of installing the meter is recorded, so that only volumes withdrawn between two meter readings are known. As a consequence, charging different prices for withdrawals at different times is impossible. This narrows the scope for demand side management and, ultimately, limits the retailer’s contribution to value creation in the industry through the development of efficient pricing options. By contrast, smart meters have the potential for retailers to develop sophisticated pricing options and services, as they provide high-frequency consumption data.

Last, physical interconnection of metering equipment to the distribution networks made a model in which meter responsibility is placed on distributors look natural. For example, safety and security issues arising when independent meter operators operate on energy and water networks do not need to be addressed by regulation in case the distributor is in charge of metering. Note, however, that those issues do not disappear when the distributor is also the meter operator. They are just addressed differently; in particular within the contractual relationship between the distributor and its subcontractors or employees.

The following changes of technology and the organisation of the energy markets may affect the optimal organisation of metering activities. First, with the introduction of smart metering meter inspectors are largely replaced by telecommunications systems connecting each meter to the head-end station. Setting up and running communications networks is a highly specialised activity, traditionally beyond core operations of gas, electricity or water companies. As a consequence, with the advent of smart meters, a larger share of investment and operating costs results from activities those distributors are not necessarily best positioned to carry out. This holds all the more in case existing telecommunications networks can be efficiently used (also) for smart metering.

Second, telecommunications bring potentially significant scale and scope economies, as the same communications infrastructure can serve multiple meters – including electricity, gas, water, heat – as well as devices providing additional services. These services can be home-related, such as security and safety monitoring, or community level services, such as those related to traffic control, waste collection, public lighting and street security. As a consequence, none of the gas, electricity and water distributors can still be regarded as the obvious candidate to deploy and manage the communication infrastructure shared by multiple metering systems.

Third, as a result of unbundling and retail liberalisation, multiple stakeholders rely on meter data to settle economic transactions, whereas in the traditional vertically integrated monopoly regime the utility was basically the only user of meter data. As discussed in chapter 2, suppliers need meter data to design price options as well as to invoice consumers. Load aggregators, often the suppliers themselves, need meter data to assess each consumer's potential for demand management. The transmission and distribution system operators need meter data to invoice retailers for network services provided to their clients. The system operator needs meter data to assess balance responsible entities' imbalances as well as balancing actions delivered by load aggregators.

Fourth, smart metering systems can perform several functions besides supplying data necessary for billing. These include:

- services to distributors, such as information on service availability and quality;

- remote activation/deactivation of consumer's electric appliances, including control of distributed generation and storage units;
- conveying information to consumers, on a continuous basis, on the level and possibly cost of their energy consumption.

Since smart meters perform multiple functions and different parties benefit from them, no obvious candidate to take on meter responsibilities can be identified among the users of the metering system. In particular, the case for placing overall metering responsibility on energy distributors is weakened when distributors stop acting as franchised retailers, losing the role of consumer's primary interface.

In some European countries, concerns that distributors carry out metering activities in a way that discriminates in favour of their affiliate retail business have been expressed. In this respect, allocating meter responsibilities to a party not active, directly nor indirectly, in the retail market would avoid any risk (or incentive) of discrimination, relieving regulation from the burden of ensuring neutrality of meter operations.

Finally, liberalisation and access regulation, in particular telecommunications local loop unbundling, have provided regulators and market participants extensive experience on technical, organisational and legal issues related to access to network facilities by third parties. Therefore, safety and responsibility issues arising in case meters were installed and maintained by a party different from the distributor can now be addressed, leveraging on a well-tested set of regulatory and contractual tools.

In conclusion, developments both in metering technology and in the organisation of energy markets have weakened the case for integration of the metering and the distribution network activities on an industry by industry basis. As a consequence, the allocation of metering responsibility needs to be reconsidered.

4.2 Possible forms of organisation for metering services

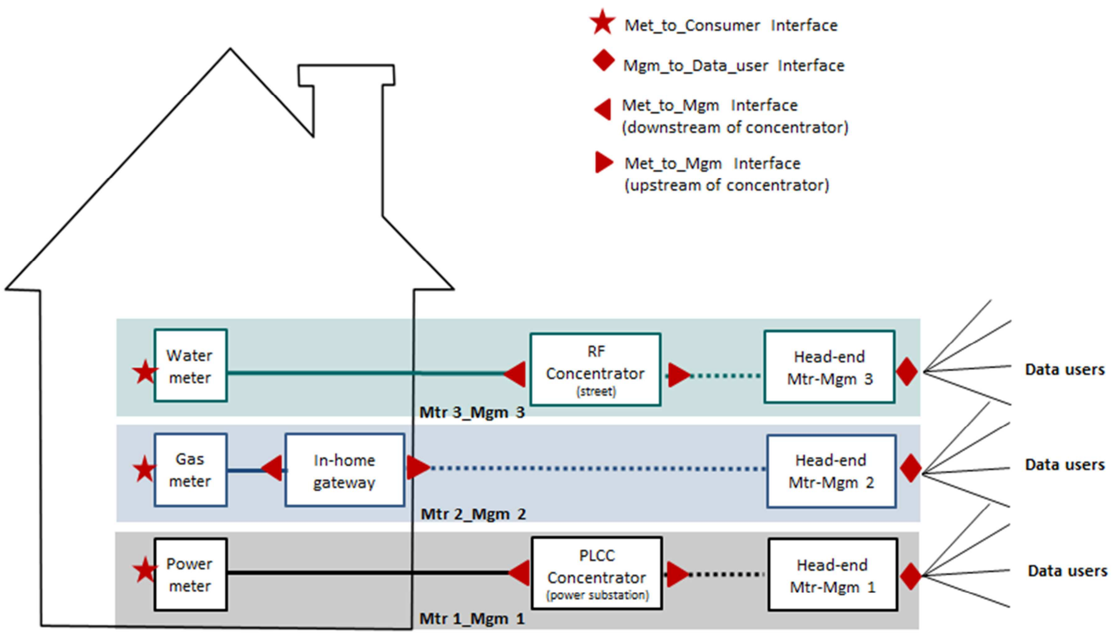
This section characterises different organisational settings for supply of metering services. Two options will be considered: a liberalised setting, where multiple competing operators supply meter availability and data management services, and a monopoly setting.

Liberalised setting

In the liberalised model for metering services, multiple competing operators supply meter availability and data management services.

Figure 10 illustrates a possible outcome of liberalised markets for metering services. A consumer has chosen different suppliers of gas, electricity and water. Each supplier has selected a different (for the moment vertically integrated) supplier of metering services (Met-1/Mgm-1, Met-2/Mgm-2, Met-3/Mgm-3). Each metering service provider operates a different technology: Met-1/Mgm-1 runs a PLCC system over the power distribution network; Met-2/Mgm-2 implements short-distance radio transmission to a gateway in the consumer's home; Met-3/Mgm-3 implements long-distance radio transmission with street-level receivers.[65]

Figure 10 - Illustration of a possible liberalised market for metering services



[65] Technological options are discussed in section 2.3.

Competition in metering activities requires that some interfaces be standardised in order to ensure interoperability of equipment. The very minimal set of interfaces needing standardisation is:[66]

- *Met_to_Consumer*: the interface between the electricity (and gas) meter and the consumer's home-automation system. Without standardisation of this interface, if consumers switch electricity (or gas) supplier, their home-automation systems could turn out to be incompatible with the meter equipment supplied by the meter operator appointed by the new energy supplier;
- *Mgm_to_Data-users*: the interface between data manager's head-end system and the data users. Without standardisation of this interface, data users might not be able to receive data from all data managers.

Standardisation of *Met_to_Consumer* and *Mgm_to_Data-users* equipment supports:

- Competition among vertically integrated suppliers of metering services;
- Non-discriminatory access to meter data by data users and to the metering communication channel by providers of remote load management services. In particular, users can access meter data and send load management signals through the head-end system's interface.

Competition among vertically separated providers of meter availability or data management services requires further standardisation. In particular, *Met_to_Mgm* interfaces must be standardised if multiple data managers are to be able to use the same meter's functionalities to access meter data or convey load management signals.

Standardisation of *Met_to_Mgm* interface may be implemented either upstream or downstream of the concentrator, as shown in Figure 10. Standardisation upstream of the concentrator makes it possible to each meter availability supplier to implement its own communication technology between meters and the concentrator. However, concentrators and meters implemented by different meter availability providers might not be interoperable. In this approach, therefore, suppliers of meter availability services are the obvious owners of concentrators.

[66] For simplicity, reference to water meter interfaces is omitted here, as water supply is in most countries a (local) monopoly. In case competition in water supply was introduced, the same requirements presented for electricity and water would hold for water meters.

The alternative approach consists in standardising *Met_to_Mgm* interface downstream of the concentrator. Standardisation downstream of concentrator makes each concentrator interoperable with all meters. However, standardisation downstream of concentrator constrains the choice of communication technology between meters and the concentrator. For example, in the UK, in-home meter data gateways implement short-distance radio communications with all meters. In this approach, therefore, suppliers of data management service are the obvious owners of concentrators.

Once interfaces are standardised, competition among multiple suppliers of meter availability and data management services can take place.

In a liberalised setting, market forces determine how ownership of, or more generally rights on, metering assets are subdivided between meter availability and data management providers. This holds in particular for data concentrators in radio-based networks, which interact with the information systems of meter availability and data management providers.

Market participants may exploit cost-saving opportunities through contracting with each other; this is expected to lead to overall cost minimisation. To achieve these cost savings as well as to prevent inefficient duplication of concentrators, standardisation of the *Met_to_Mgm* interface downstream of concentrators is necessary. Multiple suppliers of data management service could contractually agree to share the same concentrator.

More generally, market participants can contractually reallocate most of the rights or obligations related to metering. For example, a consumer could require his or her electricity and gas suppliers to use a (same) meter provider of his/her choice. This arrangement might be useful, for example, for large buildings where a set of services, including security, heating and maintenance is supplied by the same provider, and such supplier can efficiently deliver also metering services.

Monopoly models

Monopoly can be enforced on meter availability, data management or both sets of services. Monopoly of meter availability service entails that a firm has the exclusive right – and the corresponding obligation – to make meter functionalities available.

Monopoly of meter availability services can be awarded separately for gas, electricity and water metering and have different geographical scope. However, the qualifying element of this arrangement is that for each consumer one firm only can provide meter availability service.

Monopoly of data management service means that one firm has access to meter's functionalities in order to collect data and convey load management signals. Monopoly of data management services can be awarded separately for gas, electricity and water metering and have different geographical scope. The qualifying element of this arrangement is that, for each meter, only one firm can provide data management services.

In case either meter availability or data management service is a monopoly, the supplier of the monopolised service will interact with multiple competing firms supplying the other service. In case both services are monopolised, interaction will take place between monopolists.

The following sections discuss legal constraints to the creation of exclusive rights. It can already be noted here that monopoly positions, whether legal or *de facto*, must be typically accompanied by regulation to set the content and quality of the service and to prevent the exercise of market power. The following sections will, however, also consider arrangements in which the monopolist is selected through a tendering process, which provides market power discipline.

Finally, in a legally established monopoly setting, the government identifies activities (and assets) falling within the scope of the monopoly. Therefore, contrary to what happens in liberalised settings, an administrative decision determines how ownership of (or at last responsibility on) metering assets is subdivided between meter availability and data management providers. In the UK, for example, communication gateways[67] are placed within the scope of data management activities.

4.3 Competition and regulation of metering services

This section discusses the relative merits of liberalised and monopoly organisation of the supply of metering services.

[67] I.e. concentrators placed in the consumer's home.

In order to focus on the special features of metering and energy supply, the analysis is developed under the following assumptions:

- Standardisation of interfaces is fully effective;
- In the liberalised setting, no violations of competition law take place, including cartels among meter service providers, abuses in the form of refuse to interconnect systems and discrimination in the provision of metering services;
- Natural monopoly conditions do not hold in supply of meter availability or data management service. In other words, it is assumed that a competitive organisation of the metering services does not lead to unexploited scale economies;
- Rate base/rate of return regulation is implemented in the monopoly settings. For the purpose of this analysis, this implies that regulation is fully effective in addressing market power. In particular, regulation prevents that the price for metering services is set above average cost. Therefore, any regulation drawbacks take the form of inefficiency, i.e. of cost being higher than the minimum possible;
- Data protection requirements are met in all settings, even though different scenarios might have different implications in terms of available tools for, cost and likely effectiveness of data protection (analysed in chapter 5).

The rest of the section is organised as follows. First, it discusses the relative merits of liberalised and monopoly models for the supply of meter availability and data management services for electricity and gas. Then, we discuss how assumptions alternative to those listed above would affect our assessment of the organizational models. Finally, the specific features of water are discussed.

Organisation of meter availability services

The merits of a liberalised organisation of meter availability services, compared to a monopoly setting, should be assessed by investigating costs and benefits of alternative arrangements in terms of:

- tailoring of services to customer's preferences;
- innovation;

- metering service cost;
- cost of industry processes based on meter data;
- market power in the supply of metering services.[68]

The report discusses next how metering technology and the specific characteristics of energy markets impact those features.

First, regarding the range of metering services, standardisation of those services is necessary in order to ensure smooth functioning of gas and electricity markets. This is the case because in the electricity and gas industry a large number of transactions involving multiple parties are settled based on meter data, through automated systems.

As discussed above, the need for coordination among multiple users of meter information constrains the content of metering services. As far as meter availability service is concerned, standardisation is necessary on features such as the available choice of frequency of meter data collection and measurement precision of the metrological unit. Further constraints on metering equipment result from the need to ensure interoperability of meters communication systems, remote load management systems and consumers' electric appliances. Since much of the design of metering services is not under the meter operator's control, the ability of competing providers of meter availability to differentiate their offerings appears limited. It is hard to foresee "premium metering services" beyond the fully-standardised basic service that comprises: *a)* making available high-frequency consumption data supporting market transactions to entitled stakeholders, *b)* allowing consumers to extract from the meter real-time data on consumption and in some implementations.[69,70]

The need for standardisation affects the selection of technology as well. It does so by restricting the range of multiple technologies that can be implemented at the same time by competing suppliers of meter availability service. As the UK experience shows, even in a liberalised settings a wide range

[68] Recall the assumption of a rate/base rate of return regulation fully effective in curbing market power but possibly less so in inducing cost minimization.
[69] Section 3.1 discusses among others the merits of including among the basic metering services the ability to convey load control signals sent by load managers and/or distributors to remotely control electrical equipment installed at the customer's.
[70] It is instead more likely that service innovation will flourish in services based on meter data, including in particular energy pricing and demand response.

of technical features of the metering system – which will have to be complied to by all suppliers of metering services – are being set through highly collegial processes, with large involvement of industry participants and, in particular, data users. Therefore, little room remains for competition to select among alternative technologies. More generally, it is hard to foresee radical differences between the decision-making process leading the selection of metering technology in a liberalised and in a regulated monopoly environment.

However, a liberalised setting for meter availability service would make it possible to exploit synergies and scope economies with other services that might be otherwise lost. For example, it might turn out to be efficient that meter availability services be provided jointly with other building engineering and surveillance services. Such joint supply would not be possible in a monopoly setting.

To sum up, limited consumer choice and high degree of standardisation of meter availability services limit the advantage of a liberalised model, relative to regulated monopoly, in terms of diversification of selection of the optimal technology as well as of offer and service innovation.

Second, regarding cost of metering services, the cost structure of smart metering systems determines the relative merits of competition and regulated monopoly. Regulatory distortions, in terms of slack or suboptimal technology selection, are commonly believed to result from the regulated firm enjoying an information advantage over the regulator.[71] This information asymmetry is less acute in case the regulated firm's efficient cost level is well known by the regulator. In this respect, our analysis of smart metering technology suggests that a large share of total smart metering cost is accounted for by equipment installed at the consumer's premises.

The markets in which those inputs are procured are such that prediction and audit by a regulator of the metering service provider's cost is straightforward. In particular, smart meters can and typically are procured in highly competitive electronics manufacturing markets through tendering processes.[72] Presumably, the latter are easier for the regulator to audit (and if necessary govern) than a regulated firm's internal activities.

[71] See for example, J.-J. Laffont and J. Tirole, *A Theory of Incentives in Procurement and Regulation*, MIT Press, 1998.
[72] In addition, pre-tender interaction with would-be equipment suppliers may provide guidance on the selection of technology.

In conclusion, since a large share of smart metering costs is (or can be) placed outside the regulated firm's control, the advantage of liberalised models relative to regulated monopoly, in terms of inducing lower costs, can be expected to be modest.

Third, regarding cost caused by an alternative organisation for data users, compared to a monopoly organisation, a liberalised model for meter availability generates additional transaction costs to data users, in particular in case of gas or electricity supplier switch. In order to illustrate these costs recall that in a liberalised model energy retail suppliers are responsible for procuring meter availability. Therefore different gas and electricity retailers procure meter availability service from different meter companies. In this setting a consumer switching energy supplier triggers a series of transactions related to meter availability. These include:

- transfer or replacement of the meter. The new energy supplier has two options: it can either purchase meter availability services from the meter company serving the former supplier or instruct a different meter company to take responsibility for the acquired delivery point. In the latter case, the entrant meter company can either arrange a visit to the consumer's premises and replace meter equipment or agree with the incumbent supplier of meter availability service to rent meter equipment already installed at the consumer's premises. In the short to medium term, the latter option (renting) appears to be efficient. Although renting implies lower costs than replacing the meter, it requires transactions which would not be necessary if meter availability service was supplied by just one firm;
- notification of change of supplier of meter availability service. All data users must be notified that either a new meter is installed at the consumer's premises or that the old meter is now managed by a new meter operator. Such notification triggers updates of all data user's automated systems, which need to point at a new source of meter data.[73]

Fourth, due to high fixed and sunk costs and the possibly limited number of active firms, it is not sure that effective competition can be sustained in the meter availability service market. In particular, high sunk cost result in the consumer and the meter availability provider being locked in

[73] The scope of updates to data users' systems depend on the organisation of data management service. In case of monopoly data manager the change of meter and of the meter availability service provider might not affect the data users' systems. See next section.

a long-term relation, which may result in prices diverging form competitive levels if, as it typically happens, long-term contracts are not feasible.

Concerning the geographic scope of a monopoly in meter availability service, no specific study assessing scale and scope economies in this sector has been found. However, the very diverse size of existing meter operators suggests that European electricity and gas markets are large enough to accommodate multiple meter operators, each above minimum optimal scale.

Multiple monopoly suppliers of meter availability services in the same energy retail market would not dramatically complicate industry process. In fact, multiple monopoly availability providers would require that (each) data manager interact with multiple availability service providers but:

- the association between each consumer and a meter availability supplier is fixed, even if the consumer switches energy supplier;
- multiplicity of available service providers would not affect the relationship between data users and data managers.

An important advantage of multiple meter availability suppliers is the possibility for regulators to benchmark their performances. Since the same technological options are available to all countries and similar conditions determining cost of service[74] feature in multiple areas across Europe, benchmarking the behaviour of multiple national or regional monopolists may mitigate the regulator's information disadvantage.

Organisation of meter data management services

Data management shares with meter availability services some characteristics that affect the relative merits of alternative organisational models:

- the need for standardisation holds for data management services as well. In addition to the constraints created by standard interfaces discussed earlier in this report, data exchange processes among meter data manager(s) and data users must be standardised. The same holds for data validation criteria, since meter data are used to settle economic transactions among multiple parties;

[74] Including, for example, population density, coverage of existing telecommunication networks and building construction technology.

- the scope for service innovation by competing suppliers of data management service appears to be limited. In particular, recall that the core task of meter data management is enforcement of multiple data users' access rights to meter data. In a liberalised data management setting, each data user would have to interface with multiple data managers. Doing so would increase cost to data users. Avoiding such cost increase requires a high degree of standardisation of the services provided by all data managers. It also makes it necessary for data managers to agree with data users any change in the content of the service provided;
- Compared to a monopoly setting, additional transactions and information exchange are required in case of energy supplier switch in a setting with multiple suppliers of data management services. In particular, consider a model in which each energy supplier procures data management services from a different provider. Supplier switching requires, in this context, updating the incumbent and entrant data managers' access rights to meter equipment installed at the consumer's premises, in order to allow data collection. In addition, all data users need to update their systems to move to the new data source. Finally, in case past meter readings are stored by the meter data manager, the consumer's record must be transferred from the former to the new data manager.

In addition, it can be argued that a setting with multiple suppliers of data management services would likely require some form of supervision authority, in charge of controlling compliance by each data manager with the industry's rules and regulations and to assess responsibility in case of disputes on data management issues. In a broader perspective coordination among multiple (competing) data managers might add to the cost of such organisational model. It is not possible to assess these costs in our theoretical setting where mistakes and a number of frictions are ruled out, but we acknowledge that they might be relevant in a real-life context.

Contrary to meter availability, data management services appear suitable for periodic selection of the service provider through some form of bidding.[75] Such arrangements as well as their applicability to data management services are discussed hereunder.

[75] An approach along this line has been chosen in the United Kingdom.

As it is known, the usual market arrangements are based on suppliers continuously competing for clients. Supply duration, if relevant, is contractually agreed between supplier and client. Competition for the market, instead, identifies arrangements in which the supplier is selected periodically through contest and granted an exclusive right (or franchise) for a predetermined time. Service features and price are determined within the selection process, as the winning supplier is selected based on the price and possibly content of the service offered. In this approach competition among suppliers takes place (only) in the selection process.[76]

The content of meter data management franchise would be mainly characterised by the set of services provided, the duration of the obligation and the geographic scope. These are addressed below.

The definition of data management services to be provided by the franchisee can follow two broad approaches. The first one consists of defining those services in detail ahead of the franchise awarding process. In that case, the selection of the franchisee can be based on price offers. Alternatively, a large set of features characterising data management services would be defined within the award process. Following that approach, competition among would-be franchisees would take place on two broad dimensions: the content of the services to provide and their price.

Replacing the data manager at the end of a franchise period can be expected to be easier if the franchise duration is consistent with the scope and economic life-time of irreversible investments by the franchisee. Otherwise complex and typically contentious issues related to transferring assets from the incumbent to the new franchisee might arise.

Franchise durations in the range of 4-6 years appear reasonable for meter data management services, largely based on IT services. However, longer franchise durations could be considered in order to account for implementation times of the initial data management system. Alternatively, the franchise duration could be made to start only from the moment when services are actually offered.

[76] This approach is said to implements competition “for” the market, since potential providers compete for the right to become monopolist for a certain period, in place of the standard form of competition “in” the market, where multiple suppliers are active at the same time, each serving a share of the market.

Experience in other industries shows that long franchise relationships cannot generally be disciplined in full ex-ante. There is a need to adjust rights and obligations of the franchisee in line with contingencies which could materialise during the franchise period and have not been fully accounted for at the award stage. Such a need introduces elements of regulation in the relationship between the data management provider and the awarding authority.

Concerning the geographic scope, the relevant trade-off is between cost for data users to interface with multiple meter data managers and long-term advantages of multiple active meter data managers being ready to compete when franchisees are re-awarded.

With respect to costs to data users, the association between each consumer and a data manager remains in this model fixed throughout the franchise period, contrary to what happens in the competitive setting. That should limit the cost for data users of interfacing with multiple meter data managers, since the supplier of data management service does not change even if the consumer switches energy supplier.

On the advantages of multiple data managers, when franchises are re-awarded firms already active in the industry may be better informed and therefore exercise stronger competitive pressure than would-be entrant suppliers. In addition, the ability to benchmark performances[77] of multiple meter data managers may improve the awarding institution's position during the franchise periods, for example, in case renegotiation of terms of the franchise is called for by one company.

Based on the above analysis, the following characteristics making data management activities suitable to implementation of competition for the market arrangements can be identified.

Firstly, data management activities are carried out through a self-contained IT platform – combining communication services commonly sourced in a competitive market and IT systems interoperating with the users' automated systems through standardised (software) interfaces.

Secondly, IT assets are typically subject to fast depreciation, mainly because of technology dynamics. This makes it possible to limit the "franchise" duration and mitigate risk and scope for post-award renegotiation of the franchise terms between the franchisee and the awarding authority.

[77] See, for example, A. Shleifer, A theory of yardstick competition, *Rand Journal of Economics*, Vol 16, 1985.

Data management services differ from meter availability services. In particular the core input for the supply of meter availability services is assets, installed at the consumer's premises, replaced every 20+ years. Such time horizon is such that, in case competition for the market is implemented:

- If the franchise period is consistent with the meters' economic life, it will in practice be impossible at the time of the award to fix prices and terms of supply of meter availability services for the duration of the franchise. Post-award renegotiation between the franchisee and the awarding authority will take place, bringing the outcome of a competition for the market model closer to that of regulated monopoly;
- If the franchise period is shorter, potentially complicated asset valuation issues might arise in case the franchise is awarded to a supplier different from the incumbent.

Finally, for the following reasons, different organisations of data management services are not likely to have materially different impact on innovation activity:

- Because of the nature and of the scope of data management activities, innovation can be expected to be imported from the ICT sector, rather than developed specifically for the metering industry. Therefore the organisation of the metering sector can be expected to have little bearing on technology development;
- Since smart meters remain in place for many years, their technical features may limit possibility of implementing innovation in data management during their economic life. For example, a new telecommunication technology to transfer data from the meter to the head end system might not be sensible to implement if it requires modification of millions of meters' hardware.

However, a model in which data management is periodically tendered-off does not appear to necessarily provide weaker incentives to innovate compared to usual market arrangements. In fact, in a framework based on competition for the market, the innovator is shielded from competition and prices and supply terms are broadly fixed throughout the franchise period. Therefore the supplier can fully appropriate the benefits of innovation through the franchise period. The benefits of innovation should then be transferred to consumers in the form of lower prices when the franchise is re-awarded.

Further considerations

The assessment made in this report on the relative merits of alternative organisational models for supply of metering availability and data management services is based on a number of assumptions and it presented with reference to the energy industry. This section discusses how departures from those assumptions affect our results. It also briefly considers specific features of the water industry.

First, it was assumed that standardisation of interfaces is fully effective. In case this condition does not hold the assessment of relative merits of alternative organisational settings tilts in favour of models with single supplier, characterised by fewer interfaces.

Second, it was assumed that no violation of competition law, such as cartels among meter service providers, abuses in the form of refuse to interconnect systems or discrimination in the provision of metering services, will occur. If imperfections of competition policy intervention are accounted for, market power issues arise in the liberalised model. In case these issues called for regulation, the difference between the market-based and the regulated monopoly settings reduce.

Third, it was assumed that a stylised rate base/rate of return mechanism is implemented in the regulated settings. A rate of return mechanism allows the regulated firm to cover incurred operating and capital costs. This means, on the one hand, that regulation is fully effective in curbing market power, i.e. in preventing that the price for metering services be set above cost. However, the mechanism may provide little incentive to minimise supply cost, as cost reductions turn into lower prices and therefore do not result in greater profits for the regulated firm. Price-caps are the opposite end of the range of regulatory mechanisms. Such mechanism set prices for regulated services for a certain period of time, independently of actually incurred cost. That provides incentives to the firm minimise cost, since savings turn into profits while the price remains fixed. However, with price caps wealth transfers beyond what would be necessary to cover cost of service generally take place from consumers to the regulated firm.[78] Minimising the regulated company's extra-profits through price capping is a prominent objective of regulators.

[78] A classic reference regarding the properties of alternative regulatory schemes is: Laffont and Tirole *A Theory of Incentives in Procurement and Regulation*, MIT Press, 1993.

The assumption on the regulatory mechanism is such that regulatory imperfections may result in inefficiency, i.e. in actual costs greater than minimum possible costs. However, no price-cost gap occurs. Regulatory imperfections in price-cap mechanisms, instead, result in typically unwanted (but necessary) wealth transfers from consumers to the regulated firm.[79] Regulatory mechanisms implemented in practice are typically a mix of both stylised mechanisms.

When assessing alternative organisations for metering services, rate base/rate of return may be suboptimal in terms of balancing between market power mitigation and productive efficiency. In that case a superior regulatory mechanism would, *ceteris paribus*, make the setting with regulation more attractive.

Fourth, it was assumed that natural monopoly conditions do not hold in supply of meter availability or data management service.[80] In addition, it was implicitly assumed that competitive organisation of the metering services does not lead to unexploited scale economies. Relaxing this assumption would, *ceteris paribus*, make settings with multiple suppliers of metering service less attractive than monopoly.

Fifth, it was assumed that privacy issues are effectively dealt with in all settings. In fact, different organisations of metering services might make data protection more or less cumbersome. On the one hand, enforcing privacy might be more difficult if sensitive data is split among multiple firms. In particular, this holds if sensitive information about consumer's historic consumption needs to change hand when the consumer switches energy supplier. On the other hand, failures to protect sensitive data might cause larger social cost if information is concentrated in one system. The relationship between privacy issues and organisation of the smart metering system will be further investigated in chapter 5.

Finally, regarding the smart metering in the water sector, the discussion of the relative merits of competition and regulated monopoly should in principle not be different from what has been developed in this section regarding electricity. However, water retailing is typically organised as a local vertically integrated monopoly. Competitive arrangements for metering do therefore not

[79] A deadweight loss due to price above marginal costs occurs too.

[80] The very diverse size of existing meter operators suggests that European electricity and gas markets are large enough to accommodate multiple meter operators, each above the minimum optimal scale.

appear to be consistent with the monopoly organisation prevalent in water supply. This is so because the monopoly water supplier would become the sole buyer of metering services, which it would then embed into the water supply service. Nevertheless, in case a multi-utility smart metering system was set up, harmonising the organisation of water and energy data management services might be cost effective.

4.4 Legal and regulatory framework

The previous section set out the economic considerations pertaining to the roll-out and organisation of smart metering. However, these activities are not taking place in a legal vacuum. A host of legal provisions apply, both at EU and national level. For the purpose of the discussion, the focus is put on EU law, which largely influences national law and, at the same time, imposes boundaries on it.

By and large, the roll-out and organisation of smart metering gives rise to the following legal questions:

1. What is the applicable legal framework?
2. What room is there for public authorities to intervene in the roll-out process and the market structure?
3. What constraints does the applicable law impose (or allow to impose) on the behaviour of firms active in smart metering?

Each question will be discussed in turn.

4.4.1 Applicable legal framework

In the discussion of smart metering, it is often assumed that either energy regulation applies, or that it is a matter of applying energy and electronic communications regulation side by side. In reality, both energy and electronic communications regulation are sector-specific frameworks, which are meant to apply within their relatively well-defined respective scopes. Within these scopes, they apply over and above the generally applicable EU law, and outside of these scopes, only that generally applicable EU law remains. The resulting picture is thus of three applicable frameworks.

4.4.1.1 General EU law: competition law and internal market

The starting point is the set of default rules that applies across the board to all economic activity, namely EU competition law and the provisions concerning the internal market. EU competition law comprises not only the prohibition on restrictive agreements (Article 101 TFEU), the prohibition on abuses of dominant positions (Article 102 TFEU) and merger control (Regulation 139/2004), but also State aid control (Article 107 TFEU), the control of special and exclusive rights (Article 106(1) TFEU) and the exception for Services of General Economic Interest (SGEIs, Article 106(2) TFEU). EU internal market law covers the four freedoms – goods, services, persons and capital. For the purposes of this report, the free movement of goods (smart meters) and the freedom to provide services or to create an establishment (for services relating to smart meters) are the most relevant.

Constraints on public intervention

As far as constraints on the intervention of public authorities are concerned, Member States do retain the freedom to regulate the market actors. They can impose regulatory obligations on one or all firms on the market. These obligations can take the form of roll-out obligations, of harmonised technical terms and conditions with a view to improving interoperability between providers or of special provisions designed to regulate privacy or data protection on smart meters systems (within the boundaries set by EU legislation on the topic).

Yet that freedom is not unconstrained. EU law does not proceed from a neutral stance, but as the Treaties indicate, the EU rests on an internal market with a market economy. Accordingly, the starting point is that markets are competitive, and that intervention by the Member States on such markets needs to be justified, if such intervention is liable to interfere with the internal market or if it significantly disturbs competitive markets, for instance via public subsidies or the conferral of monopoly rights. For instance, Member State regulation that would impair the ability of providers from other Member States to enter the various markets related to smart meters would require justification.[81]

Without going into the details of every applicable provision of EU law, the analysis of Member State intervention generally runs along the following lines: the intervention must be *necessary* to remedy an identifiable problem on existing markets (taking into account any regulation already present), and it must be *proportionate* to the issue identified. The former requirement implies that some form of market failure has been identified, whereas the latter leads to an inquiry into matters such as alternative means of intervention, the parameters of the intervention and the duration of such intervention.[82] As regards proportionality, wide-ranging regulation, such as price regulation, can usually be introduced only when there is evidence that less interventionist measures – non-discrimination or transparency obligations, for instance – are ineffective.

For the purposes of this report, it is useful to explain one specific provision, Article 106 TFEU, in greater detail. Article 106(1) TFEU covers cases where Member States would decide to grant special or exclusive rights (outside of any sector-specific regulation). In the context of Article 106(1) TFEU, 'exclusive right' refers to a legal monopoly, whereas 'special right' refers to legal restrictions on market entry, whereby entry is reserved to a limited number of players, selected other than in accordance with open, transparent and non-discriminatory criteria.[83] In principle, Member States are allowed to grant special or exclusive rights; however, Article 106(1) TFEU provides that in doing so, "Member States shall neither enact nor maintain in force any measure contrary to the rules contained in the Treaties, in particular to those rules provided for in Article 18 [non-discrimination] and Articles 101 to 109 [competition rules]." The case-law under Article 106 TFEU is far from unequivocal. Recent cases have confirmed, however, that there are limits to the freedom of Member States to grant monopoly rights. Member States will breach Article 106(1) TFEU, in conjunction with Article 102 TFEU, if the scope and content of the monopoly right is such that "the undertaking in question could have been led, by the mere exercise of the exclusive or special right

[81] The effect on freedom of establishment, as set out in the example, seems the most likely case, but Member State regulation could also run afoul of the freedoms to trade goods or to provide services across borders.

[82] European Commission, *Communication on Delivering the internal electricity market and making the most of public intervention* C(2013)7243, 5 November 2013 provides a useful overview of how public intervention is to be analysed at 7-12. For a recent example where the CJEU indicated how public intervention in the energy sector is to be assessed, with reference not only to the applicable directives but to general provisions of EU law, see CJEU, Case C-265/08, *Federutility* [2010] ECR I-3377.

[83] CJEU, Case C-302/94, *BT* [1996] ECR I-6417.

conferred by the State measure, to exploit its dominant position in an abusive manner."[84] This is the case where the monopoly holder finds itself in a conflict of interest because of operations in a competitive area, where the monopoly holder also controls access to a competitive market, where the scope of the monopoly is excessive and the monopoly holder cannot suffice to satisfy demand in an area which could have been competitive, or where the monopoly holder will naturally be drawn to charge excessive prices, limit supply or fail to keep with innovation.[85]

It might be tempting for a Member State to invoke the derogation for Services of General Economic Interest (SGEIs) at Article 106(2) TFEU in order to avoid the application of Article 106(1) (or to justify any other intervention which would clash with EU law). On this point, however, the case-law of the CJEU requires that the scope of the monopoly is no larger than "necessary to enable the holder of an exclusive right to perform its task of general interest in economically acceptable conditions."[86] Furthermore, the monopoly should not extend to "specific services, severable from the service of general interest in question, if those services do not compromise the economic equilibrium of the service of general economic interest performed by the holder of the exclusive rights."[87] One recognises the necessity and proportionality components set out above. For instance, a monopoly might be justified if the firm entrusted with the provision of a SGEI were vulnerable to cream-skimming by competitors, whereby competitors would take the business of profitable customers away and leave the SGEI firm with the least profitable customers only.

Constraints on the behaviour of private actors

For the purposes of this report, the most relevant provision of EU competition law is Article 102 TFEU.[88] It applies to the conduct of any dominant firm, irrespective of whether dominance on the relevant market arises as a consequence of a legal monopoly right or simply from the factual position of the firm. While the range of conduct potentially constituting an abuse if undertaken by a dominant firm is large, for the purposes of this paper the discussion should mainly focus on (i) refusal to supply – including the supply of access to the metering equipment or to data collected by

[84] Gen Ct, Case T-169/08, *DEI*, Judgment of 20 September 2012 (nyr), para. 95.
[85] *DEI*, ibid., para. 96-119, reviewing the case-law of the CJEU.
[86] CJEU, Case C-475/99, *AmbulanzGlöckner* [2001] ECR I-8089, para. 57.
[87] Ibid. para. 59, referring to CJEU, Case C-320/91, *Corbeau* [1993] ECR I-2533.
[88] The application of Article 101 TFEU to agreements between industry players can be left out at this point in the analysis, even if it could be relevant later.

the smart meter – and (ii) tying/bundling – if a smart meter operator bundled services which competitors argue should be available separately, for instance meter availability and data management.

For both types of conduct, *Microsoft* remains the leading case. As far as refusal to supply is concerned, *Microsoft* established that, under the following conditions ('exceptional circumstances' justifying overriding the decision of the dominant firm), a refusal to supply will be found abusive if:[89]

- the refusal relates to a product or service indispensable to the exercise of a particular activity on a neighbouring market;
- the refusal is of such a kind as to exclude any effective competition on that neighbouring market;
- the refusal prevents the appearance of a new product for which there is potential consumer demand (in cases where the refusal bears on an intellectual property right);
- there is no objective justification for the refusal.

Microsoft has been widely criticised as introducing lower thresholds for findings that these conditions are met.[90] Yet more recent judgments cast a doubt on whether even these conditions are not too strict.[91]

It should be noted that the granting of discriminatory conditions for access, in a case where the dominant firm is also competing with the claimant on a neighbouring market, can be construed as a form of refusal to supply, if the mere discriminatory treatment were not enough to constitute an abuse.[92]

As for bundling and tying, *Microsoft* established a test that is relatively uncontroversial:[93]

- the tying and tied products are two separate products;

[89] Gen Ct, Case T-201/04, *Microsoft* [2007] ECR II-3601, para. 332-4.
[90] Although the case can also be explained in terms of underlying innovation policy choices: Larouche, "The European *Microsoft* case at the crossroads of competition policy and innovation" (2009) 75 Antitrust LJ 933-964.
[91] CJEU, Case C-52/09, *TeliaSonera* [2011] ECR I-527.
[92] The CJEU, in Case C-209/10, *Post Danmark,* Judgment of 27 March 2012 (nyr), despite appearing to loosen up the test for discrimination under Article 102 TFEU, was actually not concerned with a vertical integration case.
[93] *Microsoft*, para. 842-3.

- the defendant is dominant in the market for the tying product;
- the undertaking concerned does not give customers a choice to obtain the tying product without the tied product;
- the practice in question forecloses competition;
- there is no objective justification.

In the end, therefore, irrespective of the application of any existing EU sector-specific regulation, EU competition law would impose some constraints on the behaviour of dominant players in smart metering. Any such dominant firm, whether *de facto* or as a result of Member State regulation, would be prevented by EU competition law from refusing to supply competitors with access to its facilities (under the conditions set out above) or from bundling services which should be offered separately.

It should be noted that the application of EU competition law is not dependent on any market structure which would have been set in place via regulation: the mere fact that a given facility has been singled out for access in a customer request is sufficient to turn that facility into a relevant market to which competition law applies.[94] More importantly, in the EU, regulatory decisions do not pre-empt the application of competition law, so that even if a specific regulatory regime authorises a given course of conduct, EU competition law can still be applied to prohibit such conduct.[95]

Competition law remedies, however, are not usually as far-reaching as the obligations which are imposed on firms under sector-specific regulatory regimes: for instance, competition law usually refrains from any form of remedy which would imply constant long-term supervision of the defendant, for instance via price regulation (direct or rate-of-return). The preference would then go to more structural remedies, such as separation.[96]

[94] *Microsoft*, para. 335. See also CJEU, Case C-418/01, *IMS Health* [2004] ECR I-5039, para. 43-44. In Case T-374/94, *European Night Services* [1998] ECR II-3141, the General Court made it clear that regulatory market structures did not pre-empt relevant market definition for the purposes of competition law, when the Court endorsed a market definition which was at variance with the regulatory scheme introduced by the then applicable directive.
[95] This was a central issue in CJEU, Case C-208/08P, *Deutsche Telekom (Price squeeze)* [2010] ECR I-9555.
[96] See Regulation 1/2003, Article 7.

4.4.1.2 Sector-specific regulation

This section covers the two EU sector-specific regulatory frameworks which are potentially applicable to smart metering, namely energy and electronic communications regulation. There is no comparable EU sector-specific regulation pertaining to water.

Energy regulation

There has been limited discussion about the boundaries of energy regulation, in contrast to the experience with electronic communications regulation. In fact, the EU directives do not contain an overarching definition of their scope of application, relying instead on definitions of the main functions that they cover, including generation, transmission, distribution and supply (for electricity) or production, transmission, storage, distribution and supply (for gas).[97]

In the case of smart meters, we are concerned with distribution, which means "the transport of electricity on high-voltage, medium-voltage and low-voltage distribution systems with a view to its delivery to customers, but does not include supply."[98] In line with this definition, a DSO "operat[es], ensur[es] the maintenance of and, if necessary, develop[s] the distribution system in a given area and, where applicable, its interconnections with other systems and for ensuring the long-term ability of the system to meet reasonable demands for the distribution of electricity."[99] Two elements of this definition could potentially include the operation of smart metering systems, namely (i) the reference to interconnection (here with 'smart' systems) and (ii) the objective of ensuring the ability of the system to meet demand. As to (i), further definitions indicate that interconnection is conceived of as interconnection between transmission and distribution systems,[100] and not as interconnection with, for instance, electronic communications networks. As to (ii), the link between smart metering and the objective to meet demand is present, but that objective is shared with TSOs and other actors.

Furthermore, the nature of the position of DSOs is not clearly stated in Directive 2009/72. Article 24 merely requires Member States to designate one or more DSOs (or cause them to be designated), thus pointing to some form of special or exclusive right.

[97] The remainder of the discussion is conducted with reference to electricity regulation, but the provisions of the Gas Directive, Directive 2009/73 of 13 July 2009, [2009] OJ L 211/94, are similar *mutatis mutandis*.
[98] Electricity Directive, Directive 2009/72 of 13 July 2009, [2009] OJ L 211/55, Art. 2(5.).
[99] Ibid., Art. 2(6.).
[100] Ibid., Art. 2(13.) and (14.).

The precise boundaries of the DSO rights, in terms of network topology, are not set out clearly in Directive 2009/72. Judging from the definition above, the distribution network must have an entry point for energy supply, and a termination point for energy delivery to customers. Typically, the distribution network terminates where the in-building or on-premises network[101] starts, which is usually the point where the meter is located. In addition to receiving an exclusive or special right, the DSO can be made subject to public service obligations, including universal service obligations.[102]

As for the regulation of the behaviour of market parties, the DSO is subject to a number of obligations which are broadly in line with competition law remedies, such as non-discrimination in its dealing with third parties,[103] or separation from related activities in competitive markets, such as generation or supply.[104]

Electronic communications regulation

In contrast with energy regulation, the ambit of electronic communications regulation is set out in a few definitions. "Electronic communications networks" are defined very broadly as "transmission systems and, where applicable, switching or routing equipment and other resources which permit the conveyance of signals by wire, by radio, by optical or by other electromagnetic means, including satellite networks, fixed (circuit- and packet-switched, including Internet) and mobile terrestrial networks, and electricity cable systems, to the extent that they are used for the purpose of transmitting signals, networks used for radio and television broadcasting, and cable television networks, irrespective of the type of information conveyed."[105] Similarly, "electronic communications service" is defined equally broadly as "a service normally provided for remuneration which consists wholly or mainly in the conveyance of signals on electronic communications networks."[106] Finally, terminal equipment is defined in Directive 2008/63 as "equipment directly or indirectly connected to the interface of a public telecommunications

[101] I.e. the network of pipes or wires which distributes the electricity or gas throughout a building, from the meter head to power outlets or gas appliances.
[102] Ibid., Art. 3.
[103] Directive 2009/72, Art.25(2), 32.
[104] Ibid., Art. 26, 31.
[105] Directive 2002/77 of 16 September 2002 on competition in the markets for electronic communications networks and services [2002] OJ L 249/21 Art. 1(1.). The same definitions are used in the regulatory framework enacted pursuant to Article 114 TFEU: see Directive 2002/21 on a common regulatory framework for electronic communications networks and services (Framework Directive) [2002] OJ L 108/33, Art. 2(a).
[106] Directive 2002/77, ibid., Art. 1(3.), and Directive 2002/21, ibid., Art. 2(c).

network to send, process or receive information; in either case (direct or indirect), the connection may be made by wire, optical fibre or electromagnetically."[107]

As regards public intervention in electronic communications markets, the applicable directives are quite strict: by way of specification of Article 106 TFEU,[108] no special or exclusive rights are allowed over electronic communications networks, publicly available telecommunications services or terminal equipment, pursuant to Directives 2002/77[109] and 2008/63.[110] Intervention is limited to the cases covered in the Directive, as far as the regulation of wholesale relationships is concerned.[111] As for retail regulation, universal service and various consumer protection obligations are provided for in EU law; the scope of universal service in electronic communications remains limited, however, to basic voice service and low-bandwidth data.[112] On retail regulation, however, the directives effect minimal harmonisation, and Member States are free to go further, provided they respect generally applicable EU law, as set out above.[113]

When it comes to policing the behaviour of market parties, EU electronic communications regulation contains a sophisticated regime for firms holding Significant Market Power (SMP): subject to the control of the Commission, national regulatory authorities impose regulatory remedies (from a pre-defined set of options) on operators holding SMP on selected markets, following a market assessment inspired by competition law analysis. SMP obligations have been mostly imposed on fixed communications operators; for mobile operators, the only SMP obligations now in place bear on termination rates.[114]

4.4.1.3 Putting it all together

In regulatory terms, smart meter systems could potentially fall under three different regulatory regimes: some parts would fall under energy regulation, others under electronic communications

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[107] Directive 2008/63 of 20 June 2008 on competition in the markets in telecommunications terminal equipment [2008] OJ L 162/20, relevant parts only.
[108] CJEU, Case C-202/88, *France* v. *Commission* [1991] ECR I-1223 and Case C-271/90, *Spain* v. *Commission* [1992] ECR I-5835.
[109] Directive 2002/77, *supra,* Art. 2. The scope of the prohibition is restricted to "publicly available" electronic communications networks, but that is not material for the discussion here.
[110] Directive 2008/63, *supra*, Art. 2.
[111] CJEU, Case C-192/08, *TeliaSonera*[2009] ECR I-10717, Para.37 and ff.
[112] Directive 2002/22 on universal service and users' rights relating to electronic communications networks and services (Universal Service Directive) [2002] OJ L 108/51.
[113] CJEU, Case C-522/08, *TelekommunikacjaPolska* [2010] ECR I-2079.
[114] Roaming being regulated in a separate regulation.

regulation, while the rest would be left to be governed by general competition law provisions only (which apply to the first two parts as well in any event).

The following table sums up the characteristics of these three regimes:

Relevant area	**General EU law**	**Energy**	**Electronic communications**
Scope	Whole economy (in addition to sector-specific regulation)	"Distribution" and DSO	Electronic communications networks and services; terminal equipment
Public intervention: Possibility to introduce special or exclusive rights	Subject to Article 106 TFEU	Allowed for distribution	Forbidden
Public intervention: Possibility to introduce regulatory obligations	SGEI-related obligations (with the benefit of Article 106(2) TFEU if needed) Standardisation of interfaces Other obligations (comparable to EU sector-specific regimes in the next columns) if necessary and proportionate, subject to internal market and competition law (with the benefit of Article 106(2) if needed)	Universal service obligations (mandatory) Harmonisation of technical standards Regulation of specific actors, including DSOs (mandatory)	Universal service obligations (mandatory) Harmonisation of technical standards Regulation of operators with Significant Market Power (SMP) on selected markets (mandatory)
Policing behaviour of market actors: obligations	Dominant firms (Article 102 TFEU): Access, non-discrimination, unbundling	DSOs: Access, non-discrimination, separation	SMP operators: Access, non-discrimination, separation
Policing behaviour of market actors: remedies	Non-discrimination, transparency remedies, obligation to supply or to unbundle. Price regulation unlikely, separation preferred as ultimate remedy.	Non-discrimination, transparency, access, separation, price regulation	Non-discrimination, transparency, access, separation, price regulation
Enforcement	Commission, NCAs, courts	NRAs for energy	NRAs for electronic communications

4.4.2 Constraints on public intervention

A first type of public intervention, which should not be too problematic under EU law, is the standardisation of the various interfaces involved in smart metering, as described in section 3.2. By structuring the sector in segments delineated by interfaces, standardisation enables competitive markets on these segments to lift off (the alternative being competition between stand-alone proprietary smart metering systems).[115] In principle, *national* standardisation measures can have an adverse effect on the internal market, by creating barriers between Member States. However, European standardisation bodies are at work to ensure that standardisation efforts are coordinated.[116]

By the same token, intervention to create coordination mechanisms to ensure quality control and avoid/remedy operational errors should not be problematic. Those mechanisms could even be created by the private actors themselves, provided that they avoid infringing the prohibition on anti-competitive agreements at Article 101 TFEU.

Beyond that, the previous section (4.3) introduced a number of regulatory solutions that deserve closer scrutiny. For the purposes of legal analysis, it is necessary to distinguish between two separate regulatory elements:

- the obligation imposed upon a firm to deploy smart meters and/or provide service to every customer in a given area under specific terms and conditions (mandatory roll-out);
- the reservation of certain services (meter availability, data management) to a single supplier, to the exclusion of any other firm (the 'monopoly' in the proper sense).

It must be emphasised that these two elements are independent from one another, in that it is conceivable that smart meter regulation would include only one of them or both.

Each is reviewed in turn. As a starting point, no differentiation is made as between elements of smart metering – in particular meter availability and data management – unless otherwise specified.

Obligation to deploy smart meters and / or provide service to every customer

At first sight, if a Member State decides to oblige a firm to deploy smart meters and provide service to every customer, there should be little impact on competition or on the internal market, since other firms are not prevented from entering the market, if they deem it commercially viable.

[115] At the same time, by fixing boundaries between segments, standardisation obviously channels innovation along the path of the market structure that it introduces, thereby potentially foreclosing some innovation paths. When put in the balance against the advantages of standardisation, this potential loss on innovation appears bearable.
[116] See the work of the CEN-CENELEC-ETSI Smart Grid Coordination Group.

Nevertheless, the firm that is put under the regulatory obligation will end up deploying across the Member State or at the local or regional level and could accordingly derive a competitive advantage from being the established mandatory roll-out provider. This could result in a *de facto* monopoly and close the market for other providers, including those from other Member States. Accordingly, such a measure should be justifiable by reference to a market failure (necessity) and proportionate to the problem.

As for the necessity test, there are by and large two lines of justification, one transitory, the other longer-lasting. The *transitory* justification rests on the observed coordination problem with smart meter deployment in a competitive environment, as they were experienced in the UK (before the current regime was put in place) and in Germany, for instance. Essentially, for every individual customer, moving to smart metering may not be worth it at this point in time: the meter is expensive, and the energy savings may not be so considerable, especially given that the smart metering infrastructure may not be fully deployed. There are therefore a *time discrepancy* and *critical mass* problems: smart meters must be widely deployed and used in order for the benefits to be fully realised. In other words, the key issue here is to break the vicious circle which keeps customers from moving from traditional to smart meters because smart meters do not bring sufficient benefits, whereas these benefits require a sufficient mass of customers to accrue fully. It would then be justified on economics grounds to artificially kick-start smart meter deployment via mandatory roll-out.

A *longer-term* justification for mandatory roll-out would involve externalities which persist in the long term. The benefits from smart metering accrue not just to the individual consumer, but also to the supplier and the DSO, and ultimately to society as a whole by way of lower consumption. Conceivably, these externalities can only be fully internalised if a vast majority of customers are connected. A second justification might turn around *social policy* objectives, namely enabling all customers to benefit from smart metering, irrespective of location or economic means.

With respect to proportionality, the UK example shows that it is possible, for smart meter availability, to impose an obligation upon the whole sector, i.e. on a set of competing firms rather than just one. As described earlier, in the UK, all suppliers (and not the DSO) are obliged to install standardised smart meters on their customers' premises. At the same time, the UK has chosen to create a single entity (the DCC) upon which an obligation to provide data management services is imposed for the whole UK (as far as domestic customers are concerned). The DCC is designated via an open, non-discriminatory and transparent process, with a view to ensuring that the deployment is done under the most efficient conditions.

The conclusion that emerges is that mandatory roll-out as such could be justifiable. A previous section (2.3.) concluded, however, that neither the policy debates, nor the existing cost-benefit analyses do so far provide a clear case for roll-out.

Considering the current experience with smart meters, the firm upon which the obligation rests might not be able to discharge it without suffering financial losses. Presumably, these losses have to be compensated.[117] By and large, there are two means to do so. The first one is discussed below, and it involves conferring a monopoly such that the firm is able to cross-subsidise within the monopoly and recoup losses. The second one is to compensate the firm for these losses, either directly from public funds or via an industry fund. Both these solutions (public subsidy or industry fund) can potentially run against EU State aid law (Articles 107 and 108 TFEU). A full examination of the State aid implications goes beyond the scope of this paper (all the more since most Member States seem to be considering monopolies instead). Suffice it to say that, in any event, compensation cannot exceed the net cost of mandatory roll-out, defined as the difference between the performance of the firm (revenues and costs) with and without the obligation.

Exclusive rights for the service provider

As mentioned in the previous paragraph, in parallel with the obligation to roll out smart meters to all customers, a firm might also be granted an exclusive right (monopoly) over these services, meaning that no other firms are allowed to provide such services in the Member State in question. In comparison with a mandatory roll-out obligation, exclusive rights are more intrusive and as such they must be carefully assessed.

As a preliminary matter, it could be that the exclusive right is somehow covered by sector-specific energy regulation, in that its scope would fall under the definition of "distribution" which

[117] Unless it is held that the losses are compensated by the intangible goodwill arising out of being the mandatory roll-out provider, as was done for universal service in electronic communications in most Member States.

delineates the function of the DSO that can be put under monopoly pursuant to Directives 2009/72 or 2009/73. Referring back to the segments defined earlier, "meter availability" can conceivably be found to fall within "distribution", which could provide cover for an extension of the DSO monopoly to cover 'meter availability'. By the same token, however, the communication between the meter and the head-end would fall under the definition of "electronic communications" and could then not be put under monopoly. In order to preserve the competitive nature of the communications segment, the UK has designed the regulatory regime of the DCC such that it must procure communications services from existing competitors in the electronic communications sector.

Leaving aside the possibility that energy regulation would apply to cover part of an eventual monopoly, exclusive rights over smart meter systems will be analysed. Here the distinction between meter availability and data management might play an important role.

As outlined under heading 3.4.1., Article 106 TFEU provides the framework for assessing exclusive rights. While Member States are not as such prohibited from introducing exclusive rights, Article 106(1) TFEU implies that Member States may not set up exclusive rights in such a way that the holder of the exclusive right will automatically be led to breach Article 102 TFEU. If that is the case, then Article 106(2) TFEU can be used to justify the exclusive right by reference to a SGEI, as long as it can be shown that the exclusive right is both necessary and proportionate.

The case-law under Article 106(1) TFEU (when combined with Article 102, which is the most frequent application) is complex and not entirely settled.[118] In applying those provisions, the Commission and the EU courts have had to navigate around the early case-law, which stated that the grant of an exclusive right could not as such breach EU law. That case-law is sidestepped through the following construction: two separate markets are defined, A and B. A is the "core" market (for which an exclusive right would be justified for public reasons) and B is an "extension" or "neighbouring" market. One firm (the monopolist) holds an exclusive right over A, which gives it a dominant position within the meaning of Article 102 TFEU. It is also active in B. The Commission

[118] In the most recent major case, *DEI*, mentioned *supra*, the judgment of the General Court has been brought on appeal to the CJEU (Case C-553/12 P): in his opinion of 5 December 2013 in that case, Advocate-General Wathelet has sharply criticised the reasoning of the General Court and recommended that the CJEU overrule the General Court. For the purposes of the discussion here, however, both the General Court and the Advocate General point in the same direction. Their disagreement centers on what the Commission is required to prove as regards the abuse on the second market, either a concrete abuse (according to the General Court) or a general risk of abuse (according to the Advocate General).

and the EU courts then find that the exclusive right over A, which is not challenged, gives the monopolist the ability to abuse that position so as to distort competition in B. Here, a number of options are possible: the monopolist could have an exclusive right over B as well, in which the abuse would lie in the 'extension' of the dominant position from A to B, and the remedy would involve either removing the monopoly in B or splitting the monopolist in two (one firm in A and one in B). Alternatively, B could be a competitive market where the monopolist in A uses its dominant position in A to gain an advantage over its competitors in B,[119] in which case the remedy would involve separation of the monopolist's activities on A and B.

Accordingly, in the application of Article 106(1) to smart meters, much will hinge on:

(i) whether the firm holding the monopoly on smart meters or an element thereof (meter availability, data management) is also active on a neighbouring market, which would be the case is that firm is the DSO or an energy supplier; or

(ii) whether any monopoly can somehow be construed as a bundle of two markets, one being "core" and the other "extension", such that the monopoly on the extension could be questioned. For instance, considering the distinction made above between meter availability and data management, a monopoly over both could be vulnerable to that construction.

With respect to *meter availability* in particular, it follows from above that it matters who obtains the monopoly right. If it is one of the competitive suppliers, then that supplier could use the monopoly right to foster its own competitive position on the supply market at the expense of other suppliers. If the monopoly is entrusted to the DSO, the situation is less clear: if the DSO is also present on the supply market, then it becomes a matter of the strength of the unbundling between the distribution and supply functions. If the DSO is fully unbundled and not liable to be influenced by any supplier, Article 106(1) TFEU would be breached only if it could be shown, for instance, that extending the DSO monopoly to smart meter availability would lead to an undersupply of meter availability or to a failure to satisfy demand for newer services which would require, for instance, the replacement of the smart meter by another model of smart meter. This appears less likely. If the monopoly on meter availability services is given to a third party (neither a supplier nor the

[119] By way of leveraging of market power, however weak that theory of harm might be from an economic perspective.

DSO), without any link to other firms in the sector, then the scope for a breach of Article 106(1) is reduced.

In any event, the monopoly can always be justified by reference to Article 106(2) TFEU. For this, it must be shown that smart metering is an SGEI (or part of an SGEI such as the supply of energy), which should not be problematic, especially if the holder of the monopoly is also under a mandatory roll-out obligation as described above. The necessity could be shown if it can be establish that a monopoly is necessary to overcome the market failures identified above (either the transition or the longer-term case), or to ensure that the SGEI operations can be carried out without loss or cream-skimming. As far as proportionality is concerned, the result will depend on whether the monopoly is carefully limited to what is strictly necessary: its scope and duration will play a role in the analysis.

A monopoly on *data management* might create more difficulties, especially if – as is the case in most Member States so far – data management is located in head-end facilities, which are linked to the smart meters via communications services, thereby establishing a clear physical distinction between the two segments.[120] Data management does then appear as a distinct market segment of smart meter systems.

Should a data management monopoly be granted to the holder of a monopoly on meter availability, it would seem that there is room to argue that the monopoly holder will be driven to use its data management monopoly abusively. In such a case, there would be a breach of Article 106(1) TFEU, in conjunction with Article 102 TFEU. This could occur, for instance, if the data management monopolist prevented potential competitors from accessing the meter directly,[121] in a situation where these competitors would want to offer innovative services which the monopolist is not offering (more on this below under the next heading). Accordingly, if monopolies are granted over both meter availability and data management, it might be advisable to ensure that they are held by two separate entities, respectively.

[120] In that respect, the use of a home gateway located on the same premises as the smart meter, as in Germany, might stand legal scrutiny better, inasmuch as it brings meter availability and data management physically and technically close together.

[121] I.e. communicating directly with the meter without going through the head-end, or in other words requesting to purchase meter availability services without data management.

If it would be found that a monopoly on data management leads to a breach of Article 106(1) TFEU, then the monopoly could be justified using Article 106(2) TFEU. Here the arguments listed under heading 3.3 would come to bear, with the emphasis then being not so much on the need for a monopoly to ensure that an SGEI can be provided without loss, but rather on the need to overcome transaction cost problems, etc. It should be noted that this argument is strongest where, as in the UK, meter availability is left to a competitive market, thereby creating a need to coordinate in the case of supplier switching. The difference between meter availability and data management, however, is that the latter could very well be administered via a concession or procurement regime, with a limited duration in time. Under these circumstances, there is a form of competition *for* the market which limits the impact of the monopoly on competition, as discussed earlier in this report.

4.4.3 Policing the behaviour of market players

As argued above, EU law imposes some constraints on how Member States intervene in smart metering to facilitate roll-out and structure markets.

As part of that regulation, Member States might be led to regulate the behaviour of market players. The case of standardisation or mandatory roll-out was already analysed.

Beyond that, as part of their intervention, Member States might also seek to impose obligations on firms to ensure that their behaviour does not undermine the achievement of regulatory objectives. First of all, if meter availability or data management is left competitive, some regulation might be needed in order to avoid that providers would prevent customers from switching, through practices such as long-term contracts, switching fees, etc. That type of regulation is well known in both the energy[122] and electronic communications sectors,[123] and it also figures in some competition law decisions by way of conditions.[124] It goes hand in hand with standardisation: if the necessary level of technical standardisation is introduced, with a view to enabling competition to work, then its effects should not be nullified by commercial practices aimed to prevent customer switching.

Secondly, it is quite conceivable that one or more firms will hold a dominant position – or significant market power – over one or the other element of smart metering. That is so even if no

[122] Directive 2009/72, *supra*, Art. 3(5), 3(16) and Annex I. Directive 2009/73, *supra*, Art. 3(6), 3(12) and Annex I.
[123] Directive 2002/22, *supra*, Art. 20 and 30.
[124] See Commission Decision of 15 September 1999, *BiB/Open* [1999] OJ L 312/1.

monopoly right is conferred; once a single firm is entrusted with mandatory roll-out (without any legal monopoly), that firm will very likely end up *de facto* dominant. In the absence of mandatory roll-out obligation or monopoly rights, it also remains possible that a *de facto* dominant firm would emerge.[125] In the presence of significant market power, market failure could arise in the form of anti-competitive behaviour, along the lines of at least two possible theories of harm. The first one would involve a vertically-integrated dominant firm denying access to smart metering elements to competitors of its upstream or downstream operations; this is a well-known theory of harm in both competition law and regulation. The second one would arise when a dominant firm is complacent and does not keep up with innovation in and around smart meters, leading it to refuse to accommodate requests by other firms (home automators, etc.) to provide access or inputs (under commercial conditions). In principle, these matters can be addressed with competition law (more below); competition law proceedings can be drawn out, however, and it might therefore be advisable to impose regulatory obligations directly. These obligations are subject to the general requirement that they are necessary and proportionate to the aim pursued, i.e. the risk of anti-competitive behaviour must be high enough to justify them. In this respect, the Access Directive for electronic communications[126] provides a useful overview of possible regulatory obligations, listed in order of intrusiveness (which is useful to assess proportionality): transparency and non-discrimination requirements represent a first step, followed by separation (of accounting first, and later structural or legal, as the need might arise), compulsory third-party access and finally price regulation.

Next to any such regulatory obligations, one must not forget that EU competition law remains applicable. EU competition law can be implemented not just by the Commission and national competition authorities, on their own motion or following a complaint, but it can also be brought to bear via the national courts, upon an application by a third party such as a competitor (actual or prospective), a supplier or a customer. Hence, even if competition authorities would – for one reason or another – refrain from actively enforcing competition law, private complainants can always take matters in their own hands, via national courts.

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[125] In such a case (no regulatory intervention to impose mandatory roll-out or confer monopoly rights), perhaps dominance is better left for competition law to police. Nevertheless, to the extent that regulatory obligations

[126] Directive 2002/19 on access to, and interconnection of, electronic communications networks and associated facilities, (Access Directive) [2002] OJ L 108/7.

Furthermore, EU competition law can be used to supplement or correct regulation. The existence and enforcement of Member State regulation is no obstacle to the application of EU competition law, as was set out above.

For the application of EU competition law, the first step is always market definition. Regulatory categories would certainly be used as a starting point for product market definition. For instance, if there was a regulatory framework such that meter availability and data management would each be under monopoly, and entrusted to two different firms independent from any other market actor (not a DSO or energy supplier), it is quite conceivable that distribution, meter availability, data management and other services coming on top of data management would each be found to constitute separate relevant markets.[127] For sure, these services, being at different levels of the value chain, are not readily substitutable with one another.

In contrast with the above paragraph, if the regulatory framework is such that, for instance, meter availability is considered to be a mere extension of distribution activities, or meter availability and data management are integrated into one regulatory category, there is no guarantee that EU competition law would necessarily track regulation. First of all, regulatory categories are indicative but not binding for market definition.[128] Market definition must be done by reference to the established test in competition law – demand substitutability, with supply substitutability playing a secondary role – and not to regulatory categories which might not have been established with those considerations in mind. Secondly, the case-law on so-called ‘essential facilities’ has confirmed that ‘access markets’ can be validly defined, even in the absence of any transactions, as soon as third parties have requested access to a resource.[129] In other words, if a third party would request access to an element of a smart metering system (e.g. direct access to the smart meter, bypassing the head-end), this might suffice to justify the existence of a relevant market for access to that element, if it is necessary for that third-party to compete on another market.[130]

Furthermore, in line with the relevant market analysis carried out for wholesale termination markets in electronic communications, it is conceivable that, if more than one firm is operating

[127] It should also be recalled that, under EU competition law, relevant markets tend to be defined narrowly.
[128] GenCt, *European Night Services*, *supra.*
[129] CJEU, *IMS, supra*, and Gen Ct, *Microsoft*, *supra.*
[130] Note that this ‘access market’ construction can be compared with the process of breaking down the scope of a monopoly into two markets for the purposes of Article 106 TFEU, as outlined above.

smart meters, each firm would be on a separate relevant market for its own subscribers. Indeed each smart meter is linked to a specific location, and accordingly two smart meters located in two separate households are not interchangeable with one another. For a firm, the benefits derived from the smart meter in household 1 cannot be replaced by those of the smart meter in household 2. By analogy with termination, therefore, each smart meter at a specific location would be on its own market, and considering commercial and technical constraints, all the smart meters served by a firm can be aggregated into one relevant market for the purposes of market definition. That analysis holds in its simplicity as long as each location is served by only one smart meter; if competing smart meters can be installed in a single location, then the analysis becomes more complex.

Currently, the experience in most Member States – as confirmed in cost-benefit analyses – rather points to a difficulty in ensuring smart meter roll-out and take-up, as opposed to lively competition between smart meter providers.[131] If Member States properly set up the regulatory framework, with transparency and non-discrimination obligations, then in principle existing parties that might potentially want to use competition law – DSOs, energy suppliers, etc. – should be content with regulatory rights and remedies.

However, in the longer term, once smart meters are rolled out and a critical mass has been attained, smart metering could become an attractive business. Moreover, as home-automation progresses, innovative new services might be introduced, involving more elaborate home systems, of which smart meters would only be part. Presumably, the providers of these services might want to install their own smart meters or, at least, have access to existing meters on location. In such a case, these newcomers to the market could request access to elements of the smart meter system from the firm owning those elements. Even if access is refused and had never been granted to anyone else, the mere request might suffice to establish the existence of a relevant market for access to that element, upon which the firm holding the element in question obviously holds a dominant position (irrespective of any legal or *de facto* monopoly which that firm might have more broadly). If the complainant can prove the conditions for refusal to deal or a bundled offer to be in breach of Article 102 TFEU, as outlined earlier, then EU competition law might be used as a basis

[131] It seems, however, that the provision of smart metering to non-domestic/non-household customers is already competitive.

for an order to give access to elements of smart metering systems, outside of any regulatory obligation to do so. Of course, that access would only be ordered against payment of a reasonable compensation, but as *Microsoft* shows, determining the amount of compensation can be a lengthy process, and the outcome might be on the lower end of the expectations of the holder of the element (the recipient of the compensation).[132]

To conclude, irrespective of the care with which Member States might design the regulatory framework for smart metering, there is always a risk that EU competition law would subsequently be used to impose further obligations on regulated firms (or on *de facto* monopolists), including the obligation to single out elements of smart meter systems for third-party access. Of course, it is difficult – if not impossible – to predict what forms of access to smart metering systems might be required by third parties in the future, for technology and business models which do not exist now. Accordingly, the risk linked to the subsequent application of competition law cannot be easily alleviated at present.

4.5 Smart metering scenarios

The conclusions arising from the previous sections will now be brought together with reference to a set of scenarios.

This report highlights three main dimensions that characterise alternative smart metering solutions. The first dimension is the participation mode, i.e., if smart metering deployment is mandated or optional. This dimension is analysed in section 2.3.1, where it is noticed that most countries have opted for mandated deployment and reasons for that approach are discussed.

The second dimension, analysed in section 3.3, is the meter's architecture. All smart metering systems perform remote collection of high-frequency consumption data, allow local access to consumption data and remote control of some meter's functionalities. The major architectural decision is whether remote control of consumer's appliances, including distributed generation, is implemented via the smart metering system. This determines how the smart metering system interacts with home-intelligence systems.

[132] See for instance, Gen Ct, Case T-167/08, *Microsoft*, Judgment of 27th June 2012 (nyr).

The third dimension, as analysed in section 3.4, is the organisational models for the supply of metering services.

The focus of this section is set on the third dimension, i.e. the organisational model, the area in which there appears to be more room for policy discretion.

The assessment is based on the assumption that meter availability and data management services can be run by separate entities. It is, however, understood that in Germany this is impossible, within the current regulatory framework.[133] As the nature of this constraint does not appear to be technical, it is not being discussed further.

Scenario 1: competition in meter availability and data management services

In this scenario, all metering services are open to competition. Multiple firms compete in the market, to supply meter availability and data management (or gate administration) services. For example, energy and water distributors and providers of building management systems might compete to supply meter availability. Telecommunication providers, IT companies and energy suppliers might compete to supply data management.

The analysis in section 4.3 suggests that a competitive setting for meter availability services is not likely to deliver, compared to monopoly, major benefits in terms of service range, innovation and incentives to minimise cost. In addition, transaction costs for data users caused by multiple suppliers are likely to be relevant and supply of meter availability appears to be prone to market power.

A similar assessment holds for provision of data management services by multiple competing suppliers. In particular competition in the market for data management services presents challenges similar to meter availability in terms of coordination and transaction costs.

From a legal perspective, a scenario where meter availability and data management services are open to competition is attractive as, from the perspective of EU law, it presents few difficulties. The main issue is that in order to reach an effective competition, a significant amount of

[133] We notice incidentally that such provision needs to be integrated in multi utility setting, in order to establish which among the gas, electricity, and water distributors acts as the gateway administrator.

standardisation would be required. The standardisation exercise should be carried out or harmonised at EU level to avoid creating restrictions on internal market freedoms.

Among the countries that were surveyed for this report, only Germany has selected a formally liberalised organisation of all metering services, with distributors acting as default suppliers in case the consumer does not select an alternative meter operator. It is, however, understood that this model might be reviewed within the context of the smart metering program.

A variant of Scenario 1 consists in introducing a mandatory roll-out obligation, but without any further regulatory intervention. Even without a monopoly right, a mandatory roll-out could probably put the firm upon which the roll-out obligation rests in the situation of a *de facto* monopolist. The roll-out would therefore require a justification under EU law, as a proportionate response to a market failure. A number of justifications are possible, such as the need to reach a critical mass of users or the need to counter externalities.

For the remaining scenarios, the assumption is made that there is a mandatory roll-out obligation in place.

Scenario 2: regulated monopoly in meter availability services and competition in data management services

In this scenario, one firm only, subject to regulation, supplies meter availability service at each metering point while multiple providers compete to be selected to provide data management services.

The analysis in section 4.3 suggests that a regulated monopoly may be the most effective setting for meter availability service.

A monopoly organisation of meter availability raises, however, the issue of the role of energy distributors, which in most countries are currently monopoly providers of metering services. It has been argued in section 4.2 that the evolution of the energy industry's organisation has weakened the case for the distributors' involvement in the supply of metering services. In particular, as a result of unbundling, distributors are no longer the only party interested in meter data.

However, some features of energy distribution may provide grounds for extending the distributor's monopoly to the supply of meter availability. First, the distribution business is a natural monopoly, already subject to regulation in all countries and distributors are currently in charge of metering in most countries. Second, meters are physically connected between distribution networks and the consumers' systems. Assigning meter provision to distributors would keep technical and safety issues related to physical access to distribution network within the distributor. This may simplify regulation. In addition, synergies between meter provision and distribution might exist; for example, safety inspection of the last segments of the distribution network and of the meters could be jointly performed.

However, special characteristics of the distribution activity do not appear to provide justification for extending distributors' monopoly to meter data management.

The discussion of the merits of competition in data management services in Scenario 1 carries over to this scenario.

From a legal perspective, this scenario involves supplementing the *mandatory roll-out* of smart meters with a *monopoly right* on meter availability.

As for a monopoly right over meter availability, it could arguably be justified as an extension of the monopoly of the DSO over distribution, under sector-specific energy regulation, but this is not the most solid argument. Failing that argument, the monopoly right would fall to be justified on its own, here as well as a proportionate response to a market failure, for reasons probably similar to those invoked in support of mandatory roll-out. However, in such a case, in order to avoid difficulties under Article 106(1) combined with Article 102 TFEU, it would be preferable to entrust the meter availability monopoly to a firm other than the DSO or one of the energy suppliers.

Scenario 3: Monopoly with regulation for meter availability services and selection via tender of a monopolist in data management services

In this scenario a regulated monopolist supplies meter availability service in a certain area and a monopolist selected through a tendering process is responsible for data management or gateway administration for all meter points within a certain geographical area.

The discussion of the merits of a regulated monopoly and on the role of distributors as providers of meter availability services in Scenario 2 carries over to this scenario.

Awarding multi-year franchise for meter data management on sub-national scale through some form of tendering process can be an effective way to reap the benefits of competition, while avoiding coordination and transaction cost featuring when a consumer’s data manager may change on a day-by-day basis.

Note that scenarios where competition for the market is implemented for meter availability services are not considered. This is so because, as noted in section 4.3, the meter’s economic life is very long and therefore the benefits from periodically re-assigning monopoly on meter availability services via contests are limited.

From a legal perspective, Scenario 3 raises the issue of whether a monopoly over data management is justifiable. First of all, it appears difficult to sustain that a monopoly over data management would still be covered by sector-specific energy regulation; furthermore, the electronic communications component of smart metering (exchange of data between smart meter and head-end) is likely to be covered by sector-specific electronic communications regulation and cannot be monopolised.

Such monopoly would therefore most likely fall to be assessed under the general rules of the Treaties. As such, Article 106(1) TFEU recognises that Member States may create legal monopolies; the set-up of such monopolies can be scrutinised, however, for any indication that it would breach EU law (in particular Article 102 TFEU). From that perspective, a monopoly granted for a limited duration, via a competitive tendering process (“competition for the market”), is more likely to comply with EU law than a monopoly assigned directly by legislative or executive *fiat.*

It should be pointed out, however that under Articles 106(1) and 102 TFEU), a monopoly on data management might be vulnerable if it is held by the same firm as the meter availability monopoly. Such a construction could prove vulnerable to arguments based on EU law, whether in a frontal attack on the setup of the monopoly, via Article 106(1) TFEU combined with Article 102 TFEU, or a complaint against the monopoly holder on the basis of EU competition law (Article 102 TFEU). This could occur if and when smart metering becomes sufficiently attractive commercially for newcomers to want to enter the market (as direct competitors or as providers of broader services including smart metering). In that case, EU competition law might very well be applied, irrespective of the regulatory framework, to force access to those elements of the smart metering system which a complainant would require.

Scenario 4: Competition for meter availability and selection through tender of a monopolist in data management services

In this scenario meter availability services are competitively supplied and a monopolist selected through a tendering process is responsible for data management for all meter points within a certain geographical area.

Based on the economic analysis in this report, the rationale for such model is uncertain, since potential drawbacks of a liberalised setting appear, if anything, more critical for meter availability than for data management services.

In legal terms, based on the analysis of Scenarios 2 and 3, Scenario 4 appears less likely to create difficulties under EU law. At the same time, as mentioned above, there is always a risk of subsequent application of EU competition law, in such a way as to contradict the regulatory scheme.

This model is being implemented in Great Britain, where meter availability is supplied competitively (albeit with a roll-out obligation imposed on all suppliers). Next to competition on meter availability, a Data and Communication Company (DCC), which is independent from any market actors, has been selected via a procurement procedure and will receive a monopoly right on data management.

Scenario 5: Regulated monopoly in meter availability and data management services

In this scenario both meter availability and data management are supplied by regulated monopolists. In a multi-utility metering architecture, for example, each distributor could be responsible for meter availability on its network and another company would be monopolist in data management or gateway administration. All suppliers of metering services would be subject to price regulation.

The discussion of the merits of a regulated monopoly and on the role of distributors as providers of meter availability services in Scenario 2 carries over to this scenario.

As to data management, day-by-day operations of a regulated monopoly can be expected to be broadly identical to those of a monopoly awarded via a tendering process, featuring in Scenarios 3 and 4. The main difference between the two approaches is on how the monopoly supplier of data management services is selected and disciplined. In the regulated monopoly model of Scenario 5, the selection of the monopolist is a matter for the government to decide and regulation is relied upon to discipline the selected monopolist's market power. In Scenarios 3 and 4, the selection of the monopoly data manager is carried out through a tendering process, whose outcome determines also the main features of the service and price parameters.

From a legal perspective, the feasibility of a monopoly on data management has been explored under Scenario 3. In the case of Scenario 5, the impact of the data management monopoly is not mitigated by the procedure used to award it (a procurement procedure for a time-limited monopoly, resulting in a form of competition for the market). Accordingly, compared to Scenario 3, Scenario 5 is less likely to be in line with EU law. In addition, as with Scenarios 3 and 4, there is a residual risk that competition law would be applied so as to contradict the regulatory set-up, for instance by forcing the grant of third-party access to the meter (i.e. a direct dealing between the third party and the meter availability provider).

Italy is implementing this model, apparently by considering meter availability services as part of the distribution business monopoly. Exclusive rights on data management are granted to a publicly owned company, also in charge of running a centralised IT platform implementing retail supplier switching.

5. Privacy and data protection

Smart metering, for all its benefits, creates significant risks to data privacy and security. The transition from a system whereby meters were physically read on a relatively infrequent basis mainly for billing purposes to a system whereby meters are accessed remotely on a frequent basis for a larger number of purposes exposes consumers to privacy threats. The possibility of collecting detailed information on individual energy consumption use and patterns within the most private of places, homes, could lead to considerable invasions of consumer privacy, whether directly as part of smart meter operations or indirectly, as a consequences of security breaches.

This part of the report investigates whether – and if so, to which extent – the conclusions reached in the previous parts would be affected once privacy and data protection concerns are taken into account. After a brief overview of applicable laws and leading sources (5.1), the main concerns are reviewed in turn. First of all, the applicability of privacy and data protection legislation depends on whether smart metering involves *personal data* (5.2). To the extent that this is the case, this implies that some actors will qualify as *data controllers*, with the duties incumbent to this function (5.3). The constraints imposed on *data processing* are then described (5.4). Concretely, the policy discussion has resulted in recommendations for privacy concerns to be incorporated in the design of smart metering systems – so-called *Privacy by Design (PbD)* (5.5), and for *data protection impact assessments (DPIAs)* to be carried out (5.6). A number of conclusions (5.7) are finally drawn.

5.1 Applicable laws and leading sources

In the absence of any specific EU enactment concerning privacy and data protection in smart meters, the Data Protection Directive[134] and the e-Privacy Directive[135] are applicable. The Data Protection Directive, the main legislative instrument regulating privacy issues, will likely soon be replaced by a Regulation, directly applicable in all Member States, which will put an end to the cumulative and simultaneous application of different national data protection laws.[136] In contrast,

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[134] Directive 95/46 on the protection on individuals with regard to the processing of personal data and on the free movement of such data [1995] OJ L 281/31.

[135] Directive 2002/58 concerning the processing of personal data and the protection of privacy in the electronic communications sector [2002] OJ L 201/37.

[136] See Commission Communication "Safeguarding Privacy in a Connected World – A European Data Protection Framework for the 21st Century", COM (2012) 9 (25 January 2012).

the e-Privacy Directive is specific to electronic communications. Given that the bulk of smart meter systems do not constitute electronic communications services (only the data transfers between meters and head-end do), the e-Privacy Directive is not always relevant.

Despite the lack of specific provisions, the current legal framework establishes a number of principles, criteria, rights and obligations, which delineate the framework that any smart metering regulatory model should be in compliance with.

At EU level, privacy considerations have loomed large in the policy discussions surrounding the introduction of smart metering. When the European Commission set up a Smart Grids Task Force (SGTF) in 2009, in order to assist it in policy development, one of the Expert Groups, EG2, was specifically created to produce "Regulatory Recommendations for Privacy, Data Protection and cyber-security in the Smart Grid Environment." EG2 sought advice from the Working Party of Data Protection authorities set up under Article 29 of the Data Protection Directive (WP29).[137] EG2 produced its recommendations in 2011,[138] which fed into the Commission Recommendation of 9 March 2012.[139] Much of that Recommendation is concerned with data protection issues. The European Data Protection Supervisor (EDPS)[140] issued an influential opinion on that Recommendation.[141] As a consequence of that Recommendation, EG2 received as a further task the development of a DPIA template for smart grid and smart metering systems. That template was submitted to the Task Force which delivered a negative opinion on it on 22 April 2013.[142] Following further work, a revised version of the template received a positive opinion, with some reservations,

[137] This Working Party is an independent European advisory body on data protection and privacy. Its tasks are described in Article 30 of Directive 95/46/EC and Article 15 of Directive 2002/58/EC. See Opinion 12/2011 on smart metering (4 April 2011), WP 183.

[138] See Task Force Smart Grids, Expert Group 2: Regulatory Recommendations for Data Safety, Data Handling and Data Protection (16 February 2011).

[139] See, most notably, the Commission Recommendation of 9 March 2012 on preparations for the roll-out of smart metering systems [2012] OJ L 73/9.

[140] The EDPS is an independent supervisory authority that ensures that the EU institutions and bodies respect their data protection obligations, as laid down in the EU Data Protection Regulation 45/2001 on the protection of individuals with regard to the processing of personal data by the Community institutions and bodies and on the free movement of such data [2001] OJ L 8/1. The EDPS is appointed by a joint decision of the European Parliament and the Council for a term of five years, on the basis of a list drawn up by the Commission following a public call for candidates (see Article 42 (1)).

[141] See Opinion of the EDPS on the Commission Recommendation on preparations for the roll-out of smart metering systems (8 June 2012).

[142] Opinion 04/2013 on the DPIA Template for smart Grid and Smart Metering Systems prepared by Expert Group 2 of the Commission's Smart Grid Task Force (22 April 2013), WP205.

on 3 December 2013.[143] All these documents will be used as the basis for the analysis in this chapter.

5.2 Personal data versus non-personal data

The threshold issue for the applicability of privacy and data protection legislation is whether the data collected by smart metering systems constitute "personal data", within the meaning of EU data protection law. "Personal data" is defined at Article 2 of the Data Protection Directive as "any information relating to an identified or identifiable natural person ('data subject');[144] an identifiable person is one who can be identified, directly or indirectly, in particular by reference to an identification number or to one or more factors specific to his physical, physiological, mental, economic, cultural or social identity." The crucial factor is not so much that the data can provide insight into the life of private persons, but rather that they can be linked to a person.[145] Accordingly, as recognised by WP29[146] and the European Commission,[147] smart metering can entail the collection and processing of personal data. Most data – any data linked to an individual identifier, such as a meter number or any data which provides information on an individual – will be personal data, whereas aggregate data used to measure network performance, etc. or data not linked to individuals (office buildings, campuses, etc.) would not be personal data.

In this respect, one of the leading design principles is data minimisation,[148] i.e. smart metering systems should only collect and process as much personal data as is necessary.[149] This is in the interest of firms in any event, in order to limit exposure to risks related to privacy and personal data legislation. WP29 suggested that the benefits of smart metering for suppliers and DSO – in the form of improved billing, network management, etc. – could be achieved with a limited amount of personal data, for instance by limiting the frequency of meter readings, using sampling techniques for forecasting, aggregating data or limiting its retention. For certain purposes (such as forecasting,

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[143] Opinion 07/2013 on the DPIA Template for smart Grid and Smart Metering Systems prepared by Expert Group 2 of the Commission's Smart Grid Task Force (3 December 2013), WP 209.

[144] The same definition is provided in the newly revised (2013) OECD Guidelines on the protection of privacy and transborder flows of personal data, available at: <http://www.oecd.org/sti/ieconomy/privacy.htm>.

[145] See Opinion 07/2013, *supra*, p. 12.

[146] See Opinion 12/2011, supra, pp 6-8.

[147] See Commission Recommendation of 9 March 2012, *supra*, para. 6, 7 and 9.

[148] On data minimisation in particular, see Seda Gürses, Carmela Troncoso, and Claudia Diaz, "Engineering Privacy by Design", available at: <http://www.dagstuhl.de/mat/Files/11/11061/11061.DiazClaudia.Paper.pdf>.

[149] See Recommendation of 9 March 2012, *supra*., para. 18, 22-23 and Opinion 04/2013, *supra*, p.15.

network maintenance and fraud detection), it has been suggested that collection of fine-grain data of individual households could be avoided altogether. In such cases, collection of data could occur from meters that are placed at locations within the distribution network, where they are measuring aggregate consumption of a number of households (e.g., a large apartment block, a street or a district). Of course, this could increase the cost of designing and deploying smart meter systems.

5.3 Data controller and data processor

As soon as personal data is involved, one or more entities will qualify as "data controller" with respect to such data. Pursuant to article 2(d) of the Data Protection Directive, "'controller' shall mean the natural or legal person, public authority, agency or any other body which alone or jointly with others determines the purposes and means of the processing of personal data."[150] The data controller is responsible to ensure that data protection legislation is complied with, and to give the data subjects (those whose personal data has been collected) the rights to which they are entitled under data protection legislation, including the rights of information, access, rectification/deletion and objection.

The Data Protection Directive also provides for a "data processor" function, whereby the data processor is subject to the control of the controller and is therefore subject to a more limited set of duties towards the data subject.

A first issue is therefore who, amongst the various actors, qualifies as data controller or data processor.

On this point, WP29 has ventured that the supplier would be a data controller in any event, and that the DSO would also be a controller if it is in charge of installing and operating smart meter systems.[151] In the view of WP29, the central communications function (as implemented in the UK) could be a mere data processor, as long as it does not have power to control the disclosure of data to third parties (in which case it would be a controller). Third-party providers (home automators, etc.) would also be data controllers if they use personal data in their operations. Finally, WP29 adds

[150] Interestingly, in the proposal for a General Data Protection Regulation, the definition of "controller" has been slightly amended, the word "conditions" having been added next to the term "purposes and means." A controller, therefore, determines "the purposes, conditions and means of the processing": see Article 4(5) of the proposed Regulation.
[151] Opinion 12/2011, *supra*, p. 10 and ff.

that energy NRAs could also be data controllers if they use personal data for policy and research purposes.

The Commission Recommendation leaves it to Member States to specify the roles and responsibilities of controllers and processors, but the opinion of WP29 should be influential in that respect.[152]

From the above, it can already be seen that data protection legislation will bear on a large number of actors in smart metering systems. In that respect, it might not be advisable to try to design smart metering systems around the definitions of controller and processor, in order to avoid that certain parties qualify as controller, since the threshold for being a controller (determining the purposes and means of the processing of personal data) is quite rapidly fulfilled as soon as a firm makes decisions relating to personal data.

Secondly, once data controllers have been identified, these controllers must operationalise the rights of data subjects with respect to the personal data which they are processing. The obligation to inform data subjects about the processing of their personal data established by the Data Protection Directive entails that the data controller responsible for the installation and maintenance of the meter or third parties involved in the processing of the data should make clear to data subjects what information is collected from the meter and what it is used for. Moreover, data controllers must respect the rights of data subjects to access and, where appropriate, correct or delete information held about them.[153] For instance, consumers could be given direct access to their energy usage data instead of depending on selected third parties (such as the operator of the smart metering system) to access their data. This could be done via a display on the smart meter itself and/or via an open inter-face on the smart meter itself that the consumer would then be able to connect to the device of his/her choice (e.g. smart phone, laptop).[154] Alternatively, if indirect, on-line access is foreseen, via the Wide Area Network (WAN) of the operator of the smart metering system, it should be ensured that the data stored by such parties would only be accessible by the consumers themselves via secure on-line applications.

[152] Recommendation of 9 March 2012, *supra*, para. 21.
[153] See Opinion 12/2011, *supra*.
[154] Recommendation of 9 March 2012, *supra*, para.42(a).

5.4 Data Processing

Once personal data is involved and the data controller(s) identified, data protection legislation constraints the ability to process personal data by requiring that processing is done pursuant to one of a limitative list of legitimate grounds, listed in Article 7 of the Data Protection Directive. These grounds are: consent, contractual obligations, performance of public tasks, legal obligations and the legitimate interests of the data controller. In many Member States, the exact nature of the purposes for the processing has yet to be made clear or properly defined, which makes it difficult to judge on the legitimacy of the data processing. Moreover, each separate purpose has to be, in and of itself, legitimate and one legitimate purpose cannot serve to further legitimise any other. Specifically, personal data cannot be reprocessed for another purpose that is incompatible with the purpose for which they were originally collected.

In all likelihood, *consent* will be the basis for most personal data processing in smart metering. Of course, a valid consent only exists when the data subject has made a fully-informed decision, that is to say when sufficient information about the personal data processing has been given to the data subject for him to make a genuine choice. In particular, where there are a number of different functionalities, then the consent should be granular enough to reflect these multiple purposes, rather than one consent being used to legitimise possibly divergent and unrelated purposes. Last, consent has to be freely given and must therefore be capable of being revoked easily.[155]

Other grounds seem more limited in their ambit.[156] For instance, processing for the purposes of *contractual obligations* would only cover billing, processing pursuant to *public tasks* might cover the installation of smart meters in order to reduce aggregate energy consumption (but not the processing of personal data arising from these meters), and processing under *legal obligations* might cover the installation of smart meters if this is compelled by law (but again not the processing of the personal data generated by these meters). Finally, processing of personal data for the *legitimate interests* of the data controller requires a balancing between those interests and the detriment to the data subject.

[155] See Opinion 12/2011, *supra*, at 11-12.
[156] Ibid at 12-14.

To sum up, considering that data protection concerns have played a large role in the discussion of smart metering so far, it would seem advisable for firms that qualify as data controllers to seek to obtain the consent of individual consumers for as much of their data processing as possible. In all likelihood, Data Protection Authorities (which make up WP29) will construe narrowly the other available grounds for legitimate processing of personal data.

5.5 Security and data protection by design

In view of the above, and considering that smart metering systems are being conceived and deployed at a time when data protection and privacy legislation is already well established, the Commission – in line with WP29[157] and other policy makers – has recommended that the Member States insist on "Data Protection by Design" (DPbD), whereby data protection and information security features should be built into smart metering systems before they are rolled out and used extensively.[158]

Data Protection by Design seeks to embed privacy protection at every level from conception to deployment. This approach is rooted in the belief that reliable protection in a complex ecosystem can only be achieved through an integrated design approach: unless a system is developed from "ground up" with protection at its core, failure will emerge because of unexpected weaknesses. DPbD aims at safe guarding privacy by embedding data protection seamlessly across every strand of design and deployment of a product or service. DPbD is, therefore, not only about technological design. It extends to: IT systems, accountable business practices, and physical design and networked infrastructure. This integrated approach is "an important factor in avoiding falling into techno-centric solutions to a socio-technical problem."[159] In usual engineering practice, legal issues are obstacles to be overcome after a novel IT solution has been built and it is to be rolled out. DPbD entails a reversed approach, whereby systems and processes are conceived and developed with privacy protection at their core.

Despite the significance attached to DPbD, EU-level policy discussions have not gone much further than opting for DPbD. In particular, it is striking how little connection has been made between data

[157] See Opinion 12/2011, *supra*, p. 16.
[158] See Recommendation of 9 March 2012, *supra*, paras 9-10.
[159] See Seda Gürses, Carmela Troncoso, and Claudia Diaz, "Engineering Privacy by Design", available at: http://www.dagstuhl.de/mat/Files/11/11061/11061.DiazClaudia.Paper.pdf.

protection requirements and the various organisational models being put forward in different Member States. This could reflect either the early stage of development of smart metering systems or the structure of EU data protection legislation, where – in line with general principles of EU law – implementation and application is left to Member States.

5.6 Data Protection Impact Assessments (DPIAs)

In the absence of any concrete application of data protection principles to specific smart metering models, at EU level, the European Commission has recommended that data protection impact assessments (DPIAs) be carried out prior to the roll-out of smart metering systems.[160] Specifically, the Commission has recommended that:

> "The data protection impact assessment should describe the envisaged processing operations, an assessment of the risks to the rights and freedoms of data subjects, the measures envisaged to address the risks, safeguards, security measures and mechanisms to ensure the protection of personal data and to demonstrate compliance with Directive 95/46/EC, taking into account the rights and legitimate interests of data subjects and persons concerned."[161]

Moreover, Member States should ensure that the data controller or processor consults the national Data Protection Supervisory Authority on the data protection impact assessment, prior to processing.[162]

The Data Protection Directive does not make DPIAs compulsory. DPIAs are a relatively recent development in data protection law, of which smart meters are one of the first applications. Accordingly, the Commission has pursued a "soft law" approach combining a Recommendation and further guidance to the Member States in the form of a DPIA Template (developed by EG2 from the Smart Grid Task Force), which is to be applied voluntarily by industry participants. WP29 has made numerous comments and suggestions on the draft DPIA Template of EG2. In particular, WP29 seems to be concerned that the DPIA could be used to justify trade-offs between data protection requirements and other objectives. WP29 insisted that the requirements of data protection

[160] See Recommendation of 9 March 2012, *supra*, Part I, Section 3(c).
[161] See Ibid., Part I para 4.
[162] See Ibid. at paras 9, 14, 15 and Part I, Section 4 et seq. See also Opinion 04/2013, *supra*.

legislation (including the need to justify personal data processing based on one of the legitimate purposes, or the rights of data subjects to be informed) cannot be compromised. For WP29, the DPIA concerns the risks to other interests of individuals (financial losses, discrimination, criminal activities) which could arise from data protection and privacy breaches, and accordingly it is concerned more with security than with the level of data protection as such.[163]

5.7 Conclusions on privacy and data protection

The above identification and discussion of the main issues of privacy and data protection in the context of smart meters lead to a number of conclusions concerning the viability of different smart metering organisational models.

To sum up, the Member States' discretion to regulate smart metering within their respective jurisdictions has to be exercised within the limits prescribed by EU data protection law. Smart metering requires a re-assessment of the notion of personal data, since metering data (especially when taken at short intervals) can reveal sensitive information on individual persons. By now, the EU consensus is that smart metering involves personal data. Accordingly, data processing must be justifiable with respect to one of the purposes recognised in data protection legislation. Data controllers bear responsibility to ensure compliance with legislation (including through supervision of other actors involved in data processing) and to enable consumers to exert their rights. Insistence on Data Protection by Design and the difficult discussions surrounding Data Protection Impact Assessment for smart meters indicate that the Commission and the Data Protection Authorities of the Member States, acting in WP29, intend to scrutinise industry efforts more closely than might have been expected originally.

Yet in the end, EU-level discussions so far have not really bridged the gap between the requirements arising from data protection legislation and the specific organisational models being envisaged in different Member States.[164] A number of general conclusions can nevertheless be drawn from the discussion above. First of all, data protection concerns cannot be lightly brushed aside: smart metering leads to the generation and processing of personal data. While personal data

[163] Opinion 07/2013, *supra*, pp. 7-8

[164] In its first-year report, Expert Group 3 of the Smart Grid Task Force does pay lip-service to privacy and data protection concerns, without however conducting any in-depth analysis: EG3 First Year Report: Options on handling Smart Grids Data (January 2013).

processing should be minimised, many of the most interesting services to be offered as part of smart metering or using smart metering systems – some of which still have to be developed – will use personal data.

Secondly, once personal data are involved, firms involved in the processing of such data will qualify as data controllers (or as data processors if they act fully under the control of data controllers). It seems unlikely that a smart metering system can be designed in such a way that *only one* actor in the value chain is a data controller, so that this actor would be ultimately responsible for ensuring the legitimacy of personal data processing and upholding the rights of individuals with respect to such processing. Most likely, all actors that use the personal data arising out of smart metering would qualify as data controllers for their respective processing. For instance, the firm in charge of installing smart meters (meter availability as defined in heading 3) would be a data controller, provided it makes data available to the customer on the premises. The firm that uses smart meter data to inform the customer about supply choices (the supplier) would also be a data controller. The data management firm, if it is stand-alone, would also probably qualify as a data controller. This proliferation of data controllers might not be so advantageous for the individual consumer, who is then likely to be faced with a constant stream of information and requests concerning data protection, from a number of firms.

As soon as one moves away from strict compliance issues to look more broadly at risk management and at the management of consumer expectations, there might be an advantage in having one point of contact for consumers, a "trusted party" for data protection purposes. This could be the data management provider – in the UK model – or the home gateway manager – in the German model. If there is sufficient level of agreement across the sector on how to comply with data protection requirements and manage the attendant risks, then this "trusted party" could deal with data protection issues arising throughout the sector. Nevertheless, such a model would not relieve other actors – which would remain data controllers or processors – from their legal liability under data protection legislation.

Appendices

Appendix 1: Radio transmission technology for metering

Most smart metering system architectures for small consumers' implement wireless radio data transmission from meter to a concentrator or gateway, through a basically *ad hoc* network. This network is being referred here as the "local" network. Data communication from the concentrators to the head-end system typically takes place through public telecommunications networks, such as GPRS or 3G cellular networks.

This appendix presents selected information related to wireless transmission technologies deployed in local telecommunications networks in smart metering systems. Only topics relevant to the issues addressed in the report are being covered and the presentation is kept non-technical.[165]

Transmission technology implementing local communications is a crucial determinant of the metering system's cost and performance. The main drivers of the selection of the radio transmission technology for local communication networks are:

- range, the distance between meter and concentrator;
- bandwidth, the amount of data exchanged between meter and concentrator;
- efficiency; since for safety reasons gas and water meters are generally battery powered, power consumption is crucial as the need to replace batteries during the meter's lifetime may change dramatically the metering system's total cost.

Alternative smart metering architectures present different requirements in terms of transmission range. Solutions based on a gateway inside the consumer's premises, presented in section 2.3.3, require short-distance transmission as the metrological units and the gateway are close.

[165] This appendix draws extensively from: Lücke-Janssen Daniela, *Selection and design of a wireless network for Smart Metering Applications*, Elster-Instromet Profiles 1/2013

Neighbourhood area networks, such as those presented in section 2.3.2, require transmission between meter and concentrator over a longer distance.

Bandwidth requirements depend on volume of data exchanged; for example quarter-of-hour consumption data results on data to transmit that are orders of magnitude larger than, for example, total monthly consumption data. Further, in case the smart metering communication system is used to convey remote activation and deactivation signals to electrical equipment, maximum transmission delay requirements may become relevant.

Range and bandwidth are strictly related to frequency of radio waves carrying signals. *Ceteris paribus*, lower transmission frequencies allow carrying smaller amount of data but cover larger range. Further, lower frequency signals, again *ceteris paribus*, are less impeded by obstacles located on the path between transmitter and receiver, such as walls and parked vehicles.

National and multinational regulations set the type and scope of frequency use,[166] whether use of each frequency band requires license and whether charges are payable for using that band. Local smart metering systems typically use frequencies subject to so-called general allocation, which can be used without any license or charges.[167] These include in particular:

- 2.45 GHz (2.4 – 2.5 GHz): a band internationally subject to general allocation, adopted in the UK for smart metering;
- 868 MHz (863 – 870 MHz): this frequency bands are reserved in Europe for short-range wireless communication. The Wireless M-Bus described in DIN EN 13757-4 specifies the use of the 868 MHz band and is already in use in for smart metering in Germany, the Netherlands and Belgium;
- 450 Mhz with LTE technology;

[166] In particular European Telecommunications Standards Institute (ETSI) sets the maximum admissible output power for appliances operating on each frequency. The higher the output power, *ceteris paribus*, the greater the transmission range.
[167] The range of applications those bands are used for, however, may be restricted. For example, in Europe, 169 MHz is reserved for metering applications.

- 169 MHz (169.4 – 169.8125 MHz): residential gas meters with the 169 MHz communications interface are currently being designed in Italy and France. The Wireless M-Bus standard EN 13757-4 will be extended to include the use of 169 MHz.

Higher frequencies are used for short distance communications (so called SRR, as short-range radio), such as in single-family dwellings and multiple occupancy buildings, to connect multiple meters to a gateway located in the building. Long-range radio (LRR) 169 MHz is implemented when meters are connected to neighbour level concentrators.

The interaction among devices communicating through a network is governed by rules can be set out in technical specifications called communication protocols. Protocols specify the nature of a communication, the actual data exchanged and behaviours of the interconnected devices in all circumstances. Protocols are usually tailored, among the other things, to the transmission frequency used. Protocols differ in features such as:

- Number of devices that can be handled;
- Ease of connection of additional devices;
- Network topology;
- Security;
- Transmission speed;
- Power consumption;
- Availability of compatible equipment and components.

The following protocols are being developed and implemented for smart metering applications in Europe:

- DLMS (Device Language Message Specification): an international standard introduced by rule IEC 62056, CENELEC and ISO (check 61334 – 4 - 1). Its main strength appears to be the ability to integrate diverse devices. It is being used for some smart metering applications for example in the United Kingdom;

- Zigbee: it is being developed in the context of the “smart houses project” with the objective to make communication between industrial and commercial appliances easy. This protocol is deemed well-suited for communications inside buildings. A distinguishing feature of this protocol is low power consumption;
- W-MBus:[168] Wireless Meter bus is a European standard (EN 13757-X) for meter reading, originally developed for wired communication and later extended to wireless communication at 169, 433 and 868 MHz.

[168] Standardisation in Smart Grid – Uslar, Specht, Danekas, Trefke, Rohjan, Gonzalez, Rosinger, Blaker.

Appendix 2: Relation with the work of the EC Smart Grids Task Force

This Appendix maps the activities and services covered in the report on the wider set of activities considered in the report on “Options on handling smart grid data” by the Smart Grids Task Force of the expert group for regulatory recommendations for smart grid deployment (EG3) set up by the European Commission.[169]

The activities covered by the Smart Grids Task Force include:

- smart metering, with particular emphasis on the set of services that are being referred to in this report as data management;
- information exchanges implementing energy transactions such as supplier switch.

The Smart Grid Task Force develops three alternative scenarios, or cases:

Case 1: Distribution system operator as market facilitator. This scenario focuses on data management services. In this scenario distribution system operators provide data management services in a monopoly regime. Compliance of this setting with the 3rd Energy package is stated, but not demonstrated. Although meter availability services are not explicitly addressed, the scenario’s description seems to imply that distributors are also exclusive providers of meter availability services.[170]

This scenario broadly corresponds to this report’s monopoly model for both meter availability and data management services with the additional provision that energy distribution system operators be the monopoly supplier of metering services.

Case 2: Third party market facilitator. This scenario focuses on part of data management service and on information exchange and data manipulation implementing or providing inputs to industry processes. In this scenario an independent entity:

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[169] Expert Group 3 of the Smart Grid Task Force, *EG3 First year report: options on handling smart grids data*, downloadable from: http://ec.europa.eu/energy/gas_electricity/smartgrids/taskforce_en.htm.

[170] For example, the report states at page 16: “In Case I, the DSO (in the decentralised option) will integrate the smart metering activity with a number of new sub-processes added (such as remote maintenance, data capture and validation, data storage). Having one regulated entity performing the metering is an opportunity to reduce the complexity of the process”.

- enforces market participants' access rights on "commercial data", including meter data;
- could be responsible for some industry processes, including supplier switching, data aggregation and data reconciliation.

Reconciling this case with this report's organisational models is not straightforward because the "market facilitator" is meant to supply a subset of metering services. However, since the market facilitator is presented as a regulated agent, this case presents similarities with this report's monopoly model for data management service. The report by the Smart Grids Task Force does not indicate how the third party market facilitator would be selected.

Case 3: Data access point manager. This case focuses on a subset of data management service in a highly decentralised environment for energy-related transactions, including supply of metering services, which is not characterised in the Task Force paper. The main feature of this case is that consumers would select directly the parties entitled to access their meter data and appliances (for remote management). The data access point manager would then enforce those rights by controlling the interface of the consumers' devices.

Based on the highly decentralised approach to transactions associated, in the Task Force paper, with the role of data point manager, this case appears to imply competition in provision of (all) metering services.