BEUC The European Consumer Organisation

The Consumer Voice in Europe

EMPOWERING CONSUMERS THROUGH SMART METERING

BUREAU EUROPEEN DES UNIONS DES CONSOMMATEURS AISBL/DER EUROPÄISCHE VERBRAUCHERVERBAND

Rue d'Arlon 80,

B-1040 Brussels

Tel: +32 (0)2 743 15 90

Fax: +32 (0)2 740 28 02

consumers@beuc.eu

www.beuc.eu

Ref.: X/2012/030

REPORT FOR BEUC, THE EUROPEAN CONSUMER ORGANISATION

22/12/2011

Frédéric Klopfert

&

Grégoire Wallenborn

Université Libre de Bruxelles

Citation reference: Klopfert, F., Wallenborn, G., Empowering consumers through smart metering, a report for the BEUC, the European Consumer Organisation, 22 December 2011.

Executive summary

In the 'battle' of the Smart Grid which has begun questions are being asked such as who will gain? Who will lose? It is too early to tell. One thing is sure: the Smart Grid requires additional metering points. However, these metering points should not be confused with what are commonly called smart meters and are intended to be deployed in every household.

Although this uncertainty may serve the interests of some actors, we ascertain that consumers are not adequately safeguarded in the current discussions. The battle over smart meters mainly concerns the technical and economic feasibility of private interests. This is nothing historically new in the development of technology. The case of smart meters is special however because of a split-incentive problem which could result in consumers paying for equipment and services they do not need.

Many different actors (distribution system operators, energy suppliers, energy service companies, electronics manufacturers etc.) have divergent interests in the deployment of smart meters. These interests could be more or less translated into functionalities materialised into the smart meters. Many claims are made in the name of consumers, and so this report answers the following questions: what is the usefulness of smart meters for consumers? How should smart grids and meters be deployed to reach the goal of a 20% increase in energy efficiency by 2020? And how can we ensure current policies look beyond 2020 and prevent technological 'lock-in'?

This report does not intend to cover all aspects of the smart grid issue, but rather to examine the point of view of consumers, considered in their diversity, and analyse what could be a truly 'smart' meter. It is often claimed that smart meters will help households to reduce energy consumption by up to 15%. This assertion is based on a confusion between smart meters (which are typically installed in the basements of buildings) and energy consumption displays (which are readable in homes). Furthermore, analysis of 6 recent, scientific studies on the use of smart meters reveals that the actual energy savings average between 2-4% in the best cases where consumers have clearly opted for their use.

We explain this unexpectedly low result by way of the diversity of consumers and the notion of appropriation. When assessing potential energy savings we recommend considering the differences in the motivations and capabilities of potential users. Beyond information to consumers, which is necessary but not sufficient, we suggest that consumers should be allowed to experiment different configurations of the smart meters while still in the process of invention. Smart meters will only become so when consumers use them smartly and this implies that they should actively participate in the creation and definition of functionalities, usages and meanings before techno-economical drivers decide and standardise the new objects. The use of meters could also become smarter if the energy issue frame is extended by way of innovative policy.

Solutions to sustainability problems are always a combination of technological and social ingredients. Technological innovation will be needed to face the huge challenges before us. But changes in consumption patterns are also required. Therefore, technology and its social use have to co-evolve. The link between production and consumption (including energy) will change. As this evolution should be fast, its different components must be flexible.

We therefore recommend the progressive deployment of modular smart meters in accordance with the rhythm of demand. To avoid technological lock-in, consumers and meters - together with uses and meanings - have to evolve in cooperation. The modularity of the meters should enable progressive development of the functions and the uses. Consumers should be able to opt-in to different versions of meters. We describe different types of meters with different functionalities and services. In a liberalised market, consumers should be able to choose (and pay) for the service they want.

Focusing on the important concept of ‘active consumers’, throughout our research we see the grid and the uses in their heterogeneity. Consumers have different agendas and approaches which contrast with the centralised model of electricity production and collection of personal data. We thus suggest that smart data and the use of it is developed similar to the model of the ‘open source’ movement. Consumers must have access to their own consumption data, past and present, for free and the transfer of their data to other parties must require consumer consent.

Table of contents

Acronyms

CBA	Cost-benefit analysis
CEER	Council of European Energy Regulators
CHP	Combined heat and power production
CPP	Critical peak pricing
DSO	Distribution system operators
EDRP	Energy Demand Response Project
EPB	Energy Performance of Building
ESCo	Energy service companies
ESMIG	European Smart Metering Industry Group
HAN	Home Area Network
ICT	Information and communication technologies
IHD	In home display that shows electricity consumption in real time
MDM	Meter Data Management
NIALM or NILM	Non-Intrusive (Appliance) Load Monitoring
PCT	Personal carbon trading
PLC	Power Line Communication+ different norms
PV	Photovoltaic
RES	Renewable energy sources
SM	Smart meter
ToU	Time of Use
ToUT	Time of use tariff
TSO	Transmission system operators

Where is the smartness?

1.1. Introduction. Everybody needs electricity

In modern life we are all consumers of energy. We use energy to feel comfortable at home, to heat or to cool rooms, to light them, to wash our clothes and our bodies, to cook and to eat, to entertain ourselves, to move around, to travel away, etc. Whatever our jobs and activities are, we all use energy to meet different needs and desires. Today it is hardly imaginable to live without electricity. Energy is a social good and it can be argued that the access to a minimal amount of energy is coextensive with the human right "to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing and medical care and necessary social services." (Article 25 of the Universal Declaration of Human Rights).

Concurrently many arguments plead for a reduction in energy demand. Consumers are enjoined to live more frugal lives. The probable future is the necessity of a combination between sufficiency, efficiency and renewables. This is somehow translated into a kind of new morality. Companies are accused (partly with reason) of *greenwashing* their products; 'sustainable' and 'green' are the blamed adjectives that appear everywhere. However, not only does sustainability emerge as a fashionable trend, but also new social norms like the enjoinment to consume in other ways. These ways are not clear and we certainly need to make collective experiments to understand what our future might be. Social lessons have to be drawn from the results of the different experiments *we* have performed. 'We' certainly includes all consumers but it embraces all human beings as well.

We, humans in industrialised countries, are enjoined to live more frugally, but we do not know how to achieve this objective of sustainability. Thus, any promise of energy reduction appears today as an opportunity to be developed. The sense of emergency should not however lead us to hurry on ill-conceived schemes. We run indeed the risk to create lock-in situations that would be counter-efficient in the medium term, and to take measures that would benefit only a minority of consumers, and an even smaller part of humans. Smart grids are announced as the future revolution and many important actors are rushing towards smart grids, even though nobody agrees on what 'smart' precisely means. Of course we can understand that the integration of intermittent sources to the grid requires a new organisation of the production and consumption of electricity. We think however that this organisation is too often enunciated in the terms of the production side of the energy issue. A side objective of this report is to contribute to give a voice to the multitude of consumers, who are still far from being producers.

This report aims mainly at answering the following question: what is the usefulness of smart meters for residential consumers? As we observe a lot of confusion around the term 'smart meter', this first chapter is devoted to provide some clarifications. We begin with a quick presentation of the official long-term objectives of European energy policy (1.2). We then describe different possible points of view on smart meters. Many different actors have diverse interests, sometimes divergent, in the deployment of smart meters. These interests could be more or less translated into functionalities materialised into smart meters (1.3).[1] In part 1.4 we begin to search for consumers and their multiple representations. In part 1.5 we present some very important actors which will stay in the background of the report: smart meter manufacturers, telecommunication companies,

[1] We have begun the exercise of connecting the different functionalities with the different actors in Klopfert & Wallenborn 2011.

transmission system operators (TSO). We conclude with the necessity to think about energy transition in terms of co-evolution of smart meters and all their uses.

Chapter 2 reviews pieces of knowledge, both empirical and theoretical, about the use of smart meters and feedback devices by households. It starts with the description of the mainstream view which gives consumers many different powers and capabilities (2.2). Part 2.3 analyses six recent scientific European studies on the actual use of smart meters, led at a large scale. Among other results, the studies show that energy savings expectations are quite below previous statements. In the following parts of this paper, this result is explained by the diversity of consumers (2.4) and the notion of appropriation (2.5). These parts require considering the multiplicity of motivations and capabilities of potential users, and to allow consumers to create meanings about smart meters while still in the process of materialisation. We conclude that if the energy issue frame is extended, new uses of the meters could be really smart (2.6).

Chapter 3 analyses the different functionalities that are supposedly entrenched in smart meters. Four different functionalities for consumers are described and discussed: monthly feedback, real-time feedback, historical consumption day by day[2], and personalised consumption advice. Four other functionalities more in line with the interests of other actors (Supplier, DSO, ESCo) are presented. These potentials actions are assessed against the consumers' concerns. Part 3.2 proposes a solution that meets the different identified requirements of consumers. We recommend a progressive deployment of modular smart meters that follows the rhythm set by the demand. To avoid technological lock-ins, consumers and meters, together with uses and meanings, have to evolve in cooperation. The modularity of the meters should enable a progressive development of the functions and the uses. We conclude by imagining a future in which smart data and uses are developed along the model of the 'open source' movement (3.3). Seriously considering the idea of 'active consumers' we are then led to see the grid and the uses in their heterogeneity. Consumers have different agendas and approaches that contrast with the centralised model of production of electricity and of collecting data.

Chapter 4 recapitulates the recommendations scattered throughout the previous chapters.

In this report we try to focus on the following methodological principles:

- Respect the diverse interests of consumers. The plurality of consumers reminds of the diversity of households and practices.
- Open the range of possibilities before the decision is made.
- Analyse the representations of users by the other actors. Examining what is said in the name of consumers brings interesting elements about the relation between actors who are materialising smart meters.
- Check the technical feasibility of our propositions. Notably, we have verified that standards exist.
- Focus on the most recent studies on feedback devices for household energy savings.

We have considered smart meters for electricity only as, contrarily to gas and heat metering, there is an important milestone defined by the Third Energy Directive (2009/72/EC) that obliges Member States to evaluate costs and benefits of electricity smart meters.

We do not consider the issues of privacy and security, except when they have a direct impact on some possible meter functionalities.

---

[2] As it is requested by the Energy Efficiency Directive proposal COM 2011/370.

1.2. Opening the future is smart

All recent energy related Directives (Energy Performance of Buildings, Third Energy Package Directives, Energy Labelling, Eco-Design, Climate and Energy package, etc.) and even the SET plan (COM 2011/109) are oriented towards energy savings and increased energy efficiency by 2020. The reasons to do so are threefold:

- Energy dependency
- Climate Change (CO_2)
- Techno-economical (energy importation, competitiveness).

For the same three reasons, the Climate and Energy Directives (2009/28/CE to 2009/31/CE) also tackle the energy production aspect by including renewable energy sources (RES) as well as carbon capture and storage. However, integrating an important proportion of wind and solar electricity leads to two new problems: adapting the electricity grid to new injection points and adjusting the consumption to the production. Consumption will be more adapted to the production than nowadays. The Smart Grid is presented as part of the solution and it is also widely accepted that "intelligent metering is usually an inherent part of Smart Grids."(COM 2011/202)

For these and other reasons (e.g. lobbying), we see that different policies are striving for the deployment of smart grids and smart meters. It is most likely that smart grids and smart meters *can be* useful to reach the 2020 objectives. But it is also clear that the way *smart* is conceived will have concrete impacts on household practices. And that in turn will have consequences on our success or our failure to reach the efficiency target of 2020. This brings us to the question: **How should smart grids and meters be deployed to reach the goal of 20% increased energy efficiency by 2020?**

But can we afford to focus only on 2020 targets? We know that 20% energy savings can be achieved within the mainstream thinking and the current techno-economic framework. But another often mentioned policy target date is 2050. The 4th IPCC report on climate change and the previsions on the EU's energy dependency show that 2020 is not the end of our efforts, but just a starting point for real changes. The European Commission clearly states that by 2050, industrialised countries must achieve 80-95% CO_2 reduction compared to 1990 (COM 2009/39). The same applies for other critical resource- consuming activities (COM 2011/21) that are facing the issue of depletion. We therefore have to keep in mind that all decisions made for 2020 should not limit us in further actions. Any decision that would be hastily taken could limit our choices and actions in the future. **We therefore need to answer a second question: How can we ensure that current policies look beyond 2020 and prevent lock-ins?**

Huge amounts of money are going to be invested in energy systems in the coming years.[3] Important decisions will be made to improve the sustainability of the infrastructure. These decisions will be crystallised in technological solutions and material networks and devices. The irreversibility (or path-dependency) of the settlement has therefore to be pondered.

As a starting point, let us consider the goals that have to be achieved by 2020:

- Mandatory: 20% reduction of CO_2 emissions, which corresponds to 33.6% for the electricity market.

[3] "Around one trillion euros must be invested in our energy system between today and 2020 in order to meet energy policy objectives and climate goals. About half of it will be required for networks, including electricity and gas distribution and transmission, storage, and smart grids." (COM 2010/677)

- Mandatory: 20% RES and 10% within transport.
- Indicative: 20% increase in energy efficiency measured relative to business-as-usual.

And by 2050[4]:

- 80-95% reduction of CO_2 emissions with zero-emission electricity.
- Increase of electricity usage and reduction of other energy carriers (fuel, gas, etc.).
- Transport is mainly electrical.
- Reduced energy dependency.
- General reduction in resource usage (energy and other).
- Research and development of low- and post-carbon technology.

Knowing this, we need:

- On short term (2020):
  - Electricity network capable of including a maximum of RES.
  - More electricity power (due to energy carrier shifting and increasing population).
  - Energy efficiency (relative level of reduction) and energy savings (absolute level of reduction)
  - User awareness and improved 'energy literacy'.
  - More Energy Service Companies (ESCos) for final consumers, i.e. enterprises, administrations and households.
- On longer term:
  - New consumer practices and change in consumption patterns in general, including mobility.
  - Complete RES accepting grid with increased distributed generation and storage.
  - Zero-emission buildings, or even positive energy buildings.
  - New relations to space, time, others, the environment, and oneself.

The electricity transmission systems (high voltage) are already smart, for they are partially controlled through sensors and communication networks. The grid will continue to evolve, although we don't know yet exactly how it will end like. Big uncertainties remain about how to develop smart grids at the level of distribution systems and end users. We can observe that battles over standards have started. We will show why the development of open and public standards is in the interest of the consumers (see 3.3). The control over standards is a critical issue, and should not be left in the hands of actors with short-term interests.

European policy on sustainability has been reaffirmed in COM (2009) 400: "The EU should turn the crisis into an opportunity to address financial and ecological sustainability and develop a dynamic low-carbon and resource-efficient, knowledge-based, socially inclusive society, and promote this approach globally". That entails learning to think in other ways. Sustainability means being able to take account of long-term objectives (2050 but also 2100), aiming at social equity at all levels (local, national, global), respecting biodiversity and cultural diversity, and integrating intrinsic limits when searching for solutions. If current trends continue, humanity will need three planets in 2050 (WWF 2010). The rise of the global demand for natural resources is twofold: increasing demography and change in production and consumption patterns.

In the developed world, with demography under control but with high standards of living, producers and consumers are under pressure to change their practices. "Changes in sustainable consumption

[4] COM 2011/112 - A Roadmap for moving to a competitive low carbon economy in 2050.

and production show a rather mixed picture, with some progress being achieved in terms of decoupling environmental degradation and the use of natural resources from economic growth. Consumption patterns, mainly regarding energy consumption, however, show clear unfavourable developments, whereas production patterns show positive signs." (COM 2009/400). The decoupling of resource impacts from GDP is currently relative: the ecological intensity per unit of economic output declines whereas the global impact of resource use increases (Jackson 2009).

A strategy for 2050 is necessarily a strategy that takes the path of absolute decoupling. The use of non-renewable resources must, by definition, tend to zero. Depletion is not only a trend seen in oil, but also for some metals (e.g. rare earths). A large unknown factor is the amount of resources required to build the smart grid and all the technology involved. The rarefaction of some minerals (and the pollution associated to the mines) might be a limiting factor to the development of electronics and green technology.

Solutions to sustainability are always a mix of technological and social ingredients. Technology will be needed to face the huge challenge before us. And change in consumption patterns is also required. Therefore technology and its social use have to coevolve. The linkage between production and consumption (including energy) will change. As this evolution should be fast, its different components must be flexible.

1.3. Different points of view on smart meters

Many actors move around the development of smart meters, smart grids and even smart cities. They have clearly different interests that they are striving to translate into functions materialised in the smart meters. These interests are sometimes cooperative, sometimes divergent. How could the smart meter fit into the long-term objectives of sustainable energy production and consumption? The answer to this question depends on how different interests can negotiate. The balance of interests will result in different groups of functionalities for the smart meter.

We analyse the different functionalities in more details in the section 3.1, from the point of view of consumers. Here we introduce the three different points of view about the smart meter:

1) it is conceived as a tool to raise consumer awareness and promote energy savings;
2) it is considered as part of the smart grid;
3) it is a tool for changing the electricity market.

These 3 perspectives on the smart meter are presented in figure 1.

From the **increased energy awareness and savings** perspective, the smart meter should be seen as a device that brings feedback and advice to the consumer. It should also be designed in order to help households change their behaviour. This covers different topics:

- Feedback and advice displays.
- Possibility to freely get energy services[5] on the market.
- Help energy saving become a social norm.

[5] "'Energy service' means the physical benefit, utility or good derived from a combination of energy with energy efficient technology or with action, which may include the operations, maintenance and control necessary to deliver the service, which is delivered on the basis of a contract and in normal circumstances has proven to result in verifiable and measurable or estimable energy efficiency improvement or primary energy savings" (COM 2011-370).

From the **Smart Grid viewpoint**, the smart meter should act as:

- A household data collector for energy usage.
- A gateway to remotely control some appliances in order to manage an optimum production-consumption.

And finally, from the purely **economic side**, the smart meter is an adequate device to:

- Bring the load profile into the market through new tariff schemes.
- Reduce fraud.
- Reduce unpaid invoices.

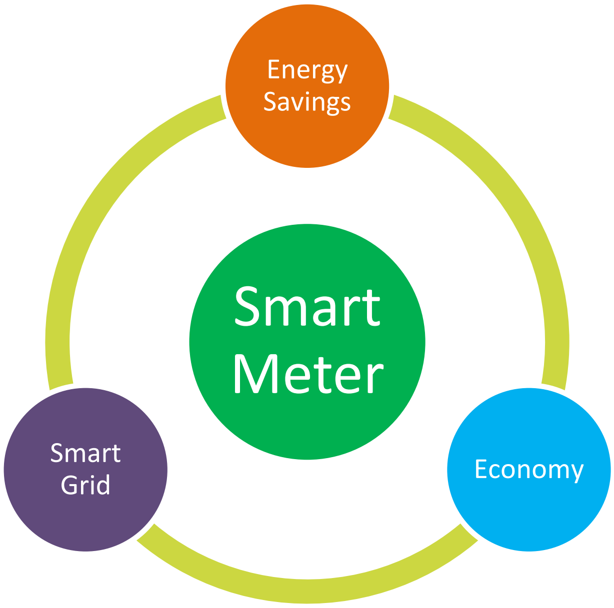


Figure 1. Three perspectives on the Smart Meter.

Is there a way to balance these three visions? Concretely, the common rules for the internal market in electricity (Directive 2009/72/CE) has led to giving, in most Member States, the responsibility of the SM deployment to the DSOs, a technology-oriented actor. Economic analyses that only take into account the DSO costs and benefits are negative if it has to pay the whole infrastructure. However, when taking into account benefits from other actors (suppliers, energy savings, etc.) the global CBA can become positive, in particular if some parts of the smart meter deployment costs can be valorised as part of the smart grid. This is the current situation in most EU countries, but the consequence is that the definition of the smart meter is in the hands of the techno-economical actors, with an underrepresentation of consumers and of “energy savings” as a main objective.

Many cost-benefit analyses have been carried out with the objective of proving that the smart meter rollout is a positive or negative business case. There are many parameters to take into consideration. Most of them have important uncertainties (such as fraud reduction due to smart meters) or are very sensitive (lifespan of data systems). Even when the global cost-benefit analysis is negative[6] there is at least one direct benefit for the user: energy savings. However, as the sum of all other costs is higher than the other direct benefits (see 3.1: remote reading of the meters, fraud detection, management

[6] Such as KEMA cost-benefit analysis for Brussels Capital Region.

of bad payers, allocation and reconciliation) it will be inevitable that the costs will in one way or another finally be re-invoiced to the consumers.

Taking seriously the role of users and the importance of energy savings, we analyse in this report the different benefits consumers can derive from the use of smart meters. The potential benefits depend on the implemented functionalities, and these functionalities have to be assessed against the possibility to change social practices.

1.4. Where are the users in the smart grid?

There is a paradox in the place consumers should occupy in the smart grid. On the one hand consumers are considered as inexistent: the grid management is delegated to the technology. On the other hand consumers are encouraged to become an active part of the new network. The idea at the basis of the smart grid is that technology can communicate information about electricity production, transmission or consumption, instantaneously (Watts) or cumulated (kWh), within spatial and temporal coordinates (at different scales). This information can automatically lead to actions, through appropriate electronic devices. Interactions are therefore automatic when it concerns only objects. When humans enter the picture, interactions are however much more difficult to programme, or even forecast.

Many claims are made in the name of the consumers. At the opposite of technological concept, in which residential consumers are considered as points of energy dissipation, the Commission wants to engage “the active participation of customers in energy markets and energy efficiency through better information about their consumption, incentives such as dynamic pricing mechanisms and appropriate ICT tools”. (SEC 2009/1295). The Council of European Energy Regulators (CEER) interprets the current European energy policy as calling for more participation from the customers: “Intelligent metering systems are promoted for several reasons in the 3rd Package; firstly with the aim to promote energy efficiency and demand-side management measures; and secondly with the aim to ensure active participation of customers in the market” (ERGEG 2011, P. 6). In its definition of “active participation”, the CEER has chosen to include the possibility for the customer to be also a producer of electricity. The European Smart Metering Industry Group has other words yet: “The core of the smart grid is the active participation of the demand side and only through the involvement and cooperation of the demand side can the 2020 objectives be met.” (ESMIG 2011, p. 6).

Consumers, users, households, customers: all these words should be interchangeable in this report. Users emphasise more the idea of an activity. Households refer to a domestic place and include the persons living there. Customers have different rights and duties towards energy suppliers. The main point however is the underrepresentation of consumers themselves. We adopt in this report the point of view of consumers, or more precisely the perspective of the residential users of electricity. We want to consider the plurality of uses and of consumers. Because everybody is an electricity consumer, adopting the consumer point of view is a more general point of view than those of specific actors. Beyond the consumers’ point of view, a universal perspective should include the environment and the future generations. This perspective has to be constructed yet, and infrastructures are part of this construction.

A general motto enjoins consumers to become more aware of their energy consumption and to “change their behaviours”. If “behaviour change” is necessary, that does not mean that everybody understands it in the same way. If we want to change the ways energy is consumed, we first have to understand how energy is actually used. Adopting the point of view of households implies that we have to start from current practices in order to figure out how they can evolve.

Household energy consumption does not occur purely for its own sake, but in the performance of practices that are socially meaningful. Practices are constituted with meanings, motivations, capabilities and objects (Warde 2005; see also 2.2). They are often deeply entrenched in habits. Consumers are neither rational nor irrational; they have developed a diversity of reasons and conventions to achieve many of their practices. These reasons and conventions can evolve at the scale of the decade. But the basic interests of all consumers should always be defended.

The idea of a Smart Grid is related to network management, mainly for peak shifting and for the integration of increased RES. Many actors are interested in the development of smart grids, but for different reasons: energy providers, DSO, TSO, public bodies, regulators, final users, energy service providers, etc. Many different devices, production units and components of the networks will have to work together. The smartness is distributed throughout the network. If there is intelligence, it will be an emerging property of the network, not a quality that can be defined a priori. A successful intelligence would mean the good use of limited resources.

1.5. Other important actors

As this report focus on consumers and smart meters, many actors will remain in the background. We describe here some of these important actors.

Energy Services Companies (ESCo) are to provide energy-related services such as audits, advice, remote maintenance and supervision, control, energy-performances contracts, etc. Their market is growing but is still mainly focussed on medium to large companies. Currently they do not provide many services to households.

The Meter Data Management (MDM) system is the technical infrastructure for communicating and managing the smart meters, the database with all metering data and the communication hub for dispatching the information to the entities that are entitled to use the data, such as suppliers for invoicing purposes. The MDM is therefore not an actor per se, but the entity that controls the database (in most Member States it is under control of the DSO) and inherits all the consumption data from all consumers.

Besides the energy-related actors that have been already described, other actors are very keen to see the development of smart meter and smart grid technologies: smart meters manufacturers and telecom operators. These purely commercial actors are interested in selling added-value to basic metering and thus promote all advanced functionalities that require high rates of data generation, transmission and storage. This clearly appears in the member list of the European Smart Meter Industry Group (ESMIG) lobby group that includes ICT companies and meter suppliers.

This lobby is present and active in many conferences on smart meters. They are clearly in the mainstream (see 2.2), which is based on the assumptions that better information delivered to consumers will automatically lead to energy savings. They have issued a report "empowering demand" (ESMIG 2011) that clearly reflects more the empowerment of their funders than the real interests of consumers.

1.6. Conclusion: Negotiating an adventure

With this report we hope to help elevate the debate while remaining loyal towards our funder, the representatives of all European consumers. We conceive consumers in their diversity and including future generations. The interests of households, users and consumers are currently not being taken sufficiently into account in the current debate about the implementation of the smart meters. Representation of users has here two meanings:

1) an organisation who can legitimately speak for others;

2) the way actual situations are described.

In this report we focus on the second meaning so that the first one might be enhanced. As consumers are the weak actors in the discussion around the split incentive of the smart meters deployment, the risk is to make them pay for objects they do not really need. The implementation of smart meters is usually seen as an essential first step towards the implementation of smart grids. This however depends on the different smart functionalities that will be developed and which have not yet been decided. We are entering in a new sociotechnical adventure. An adventure is an unusual and exciting, typically hazardous, experience or activity. Excitement should not however prevent us to see different problems. In order to avoid lock-ins and to reduce path-dependency we have to ensure that:

- The technological system is allowed to evolve in parallel to the change of usage patterns.
- The pathway towards a low carbon society remains open to any new emerging solutions.
- Learning processes are at the core of the process.
- Home automation and increasing use of electronic devices are not considered a priori as the best solution. Electronics faces indeed different issues such as new technological risks, the depletion of some resources, complexity and, last but not least, equity.

With this report we hope to bring new arguments that will help reveal the long-term interests of consumers and therefore contribute to sustainability.

We are grateful to The European Consumer Organisation for having endowed us to write this report, and in particular to Guillermo Beltrà, Monika Stajnarova and Emilien Gasc. We thank Guillermo Beltrà for his many comments on a draft version of this report. We take however the full responsibility for the left mistakes, weird ideas and odd sentences.

Towards smart consumers?

2.1 Introduction

Many actors in favour of the smart meter rollout speak in the name of consumers and state that it will help households save energy. Energy savings are even expected to pay back the global investment in smart meter infrastructure. And the adoption of smart meters by consumers, it is argued, will be painless and will even bring them different kinds of benefits. In this chapter we will analyse how far these statements are substantiated. What are the roles and actions required from consumers in the perspective of a smart meter rollout? How could users become active players of the smart grid? What does 'demand response' mean from the consumer's point of view? How are new habits and new practices adopted? We analyse what is expected from consumers, as well as how they could become active actors in the development of smart meters. Like all the other 'electricity actors', consumers will be transformed to be a full part of the smart grid. Therefore the way consumers are enrolled is crucial.

In the first section we examine what are the many assumptions behind the idea of 'active consumers'. We then review six major recent studies on the actual use of smart meters that show that energy savings are much below what has often been stated in many places and documents. In the following sections we explain this new fact by the diversity of consumers and their variable interest in the appropriation of this new device. Learning processes are important, and should be encouraged, but are not easily steered. Taking into account the users and uses (conceived as a plurality) is necessary in order to improve the efficiency of future smart grids. We conclude that receptive and active consumers require that the maximum of choices are left open when defining the policy and technical measures about smart meters. In order to give new meanings and to encourage new practices around smart meters we suggest that the whole energy framework should change.

2.2. How smart meters are mainstreamed

Energy saving by households is a big challenge because energy is both a political issue and a routinized good. We have seen in section 1.2 to which extent energy has different political dimensions. We now expand on the consumer side, mainly shaped by routines and habits. We use practice theory (Schatzki 1996, Reckwitz 2002, Shove & Pantzar 2005, Røpke 2009) to show how these habits have to be understood as a nexus of meanings, motivations, capabilities and objects.

Energy comes home under different forms, or through different carriers: oil, gas, electricity, heat, etc. Contrary to almost all other goods, energy enters buildings unnoticeably. This invisibility feature is only shared with telecom services. Energy is omnipresent in our modern ways of life and is relatively cheap, so that people can ask whether their individual efforts to save energy are worthwhile. At the same time knowledge about bills and energy saving tips is relatively low among the population (Darby 2006). This is explained by the fact that households do not consume energy but use many different appliances which provide a wide range of services (Wilhite et al., 2000).

A common answer to this huge challenge of inconspicuous consumption is to provide consumers with more understanding and control capabilities. However, we have to keep in mind that this idea of saving energy contradicts with other current social norms and values as the ideas of a comfortable home and of easy travels. To foster the development of smart meters, many discourses and documents use the following rationale: accurate and personalised information about consumption will entail energy savings, because it allows people to learn how they consume energy. Though such information is probably necessary, it is certainly not sufficient.

The point of view of the European Commission[7] is clear. “For consumers and the operation of the retail market, there are a number of benefits associated with the roll-out of smart meters that the Commission considers should be covered by the economic analysis, including:

- improved retail competition;
- energy efficiency and energy savings;
- lower bills due to better customer feedback;
- new services for consumers, including vulnerable consumers;
- improved tariff innovation with time of use tariffs;
- accurate billing;
- reduced costs and increased convenience for pre-pay;
- less environmental pollution due to reduced carbon emissions; and
- the facilitation of microgeneration, including renewable generation.”

“Improvements to the energy performance of devices used by consumers – such as appliances and smart meters – should play a greater role in monitoring or optimizing their energy consumption, allowing for possible cost savings. To this end the Commission will ensure that consumer interests are properly taken into account in technical work on labelling, energy saving information, metering and the use of ICT. The Commission will therefore research consumer behaviour and purchasing attitudes and pre-test alternative policy solutions on consumers to identify those which are likely to bring about desired behavioural change. It will also consult consumer organisations at the early stage of the process. Consumers need clear, precise and up to date information on their energy consumption – something that is rarely available today. For example, only 47% of consumers are currently aware of how much energy they consume. They also need trustworthy advice on the costs and benefits of energy efficiency investments. The Commission will address all of this in revising the legislative framework for energy efficiency policy.” (COM 2011/109**)**

Many hypotheses are made behind these statements:

- Consumers want to know more about their bills and the energy prices.
- When fully informed a consumer makes the best choice in line with his or her preferences (information leads directly to behaviour change).
- People react to external stimuli in predictable ways.
- The transaction costs of getting the right information are low, and cognitive saturation happens rarely.
- Habits can be changed through awareness rising: more reflexive users about their consumption will decide to act.
- Once settled, these habits will last.
- Households can control (or manage) their energy consumption through different strategies: cutting, trimming, switching, upgrading, shifting (Pierce et al. 2010).
- Feedback is a necessary element to control energy use more effectively: information provided by feedback is clear and self-explanatory.
- Among the overwhelming quantity of products, energy is an issue for households.
- Users are interested by increasingly sophisticated devices.

[7] European Commission, “Interpretative note on Directive 2009/72/EC.” (22-Jan-2010), p. 8

All these hypotheses are neither false nor true by themselves. They are too general with regard to the large plurality of consumers, and the huge diversity of practices involved in households. They need therefore to be assessed against scientific literature. Let's see what the most recent studies tell us.

2.3. The actual use of smart meters: analysis of 6 recent European studies

Smart meters can embody many different functionalities (cf. chapter 3). These functionalities are the translation of the interests — sometimes divergent — of different actors (consumers, DSOs, suppliers, etc.). In this section we focus on the services that have been tested within households. These services cover a large variety of experiments that are associated with a feedback on energy consumption.

From the point of view of consumers, the originality of smart meters is to provide accurate information about consumption during a given interval of time, usually known as "feedback". There are basically two kinds of feedback: historical or real time. Historical feedback gives information on what happened. Its frequency and format are variable; it requires interpretation and advice. Real time feedback gives the instantaneous consumption and draws the attention on what is happening. This therefore requires a specific display, usually designed to be mobile or clip-on, and linked to the smart meter. For users, this display device takes different names: in-house displays (IHD), Real-time display (RTD), energy monitors, etc. In this report we use the term IHD.

Through a wireless communication with the smart meter, an IHD shows the electricity consumption in near real-time. The display can show different information and advice: price signals sent by the supplier, forecast of the monthly bill, energy saving tips, etc. If it runs on batteries, the IHD can be moved around the home to check the consumption of different appliances by switching them on and off. Feedback display can also appear as an ambient feature (e.g. under the shape of changing colour lamps). This type of feedback improves the knowledge about individual consumption, but at the aggregated level: the displayed electricity consumption corresponds to the sum of all the appliances and lights. Therefore the consumer has generally a difficulty to interpret the data and to know what to do. Some feedback for the plugged appliances exists too, but this 'submetering' feedback currently requires skilled consumers that accept to spend some time installing it.

The effectiveness of feedback information depends on the type of feedback provided. First of all, the rhythm of feedback is crucial: shall it be instantaneous, every day, every week or every month? How should the information be presented: with figures, graphs, colours, diagrams, or a combination of these elements? Which benchmark is the most efficient: with oneself (historical consumption), with neighbours, with significant others? What are the interactive elements that can help consumers without puzzling them? How often information should be provided?

The oft-quoted report by Darby (2006) states that energy savings are in the range of 5-15% for direct feedback and 0-10% for indirect feedback. This magnitude is confirmed by Ehrhardt et al. (2010) and Fischer (2008). Over the past years, many documents and conferences have asserted that "smart meters" can help households to reduce their energy consumption by 10 to 15%. These discourses maintain (sometimes voluntarily) the confusion between a smart meter and an in-home display. For instance, in a recent communication (COM 2011/202), the European Commission states that "those consumers with smart meters have reduced their energy consumption by as much as 10%." And it cites a company that sells such feedback devices[8]: "In the UK, the AlertMe project allows customers to turn off appliances by web interface or mobile; in 8 months, residents have saved roughly 40 % electricity." However, new scientific studies now challenge this claim.

We have analysed six recent studies led in Europe with a significant number of participants that respect scientific standards (control group, attention to the recruitment process, description of the methodology). We have chosen studies led in Europe because there are probably some cultural effects. Observations made in the USA could be optimistic in regards of what is feasible in Europe (cf. ESMIG 2011, *Empower Demand*[9]). The six studies have published their final results in 2011; their methodology and results are summarised in table 2.1.

The Energy Demand Response Project (EDRP 2011) gathers four suppliers (EDF, E.ON, Scottish Power, SSE) under the coordination of Ofgem, the British energy regulator. During the years 2007-2010, each supplier has developed its own methodology and experiments, making it impossible to directly compare them, but enriching our knowledge about how consumers can appropriate feedback devices. Data and results have been analysed by AECOM, "a global provider of professional technical and management support services". CER (2011) is the set of reports produced by the Irish energy regulator. This organisation has focussed its study on time of use tariffs (ToUT) and on technical aspects of the communication system. The field study was conducted in 2008-2010. The German research project Intelliekon (Sustainable energy consumption in households through intelligent metering, communication and tariff systems) was launched in 2008 (Schleich et al. 2011).

A wide range of actions was tested in the different trials. These actions were proposed either alone or in combination. In order to assess the effectiveness of smart meters, non-smart meter experiments were programmed as well. 'Smart meter experiment' means that a communicating meter was installed in the household, in replacement of the old meter. In some cases, only a smart meter was installed without any other intervention: this aims at measuring the 'Hawthorne effect' i.e. the fact that people react differently when they know they are watched. But in most cases smart meters were tested in combinations with other instruments.

Smart meter experiments

- Smart meter only.
- Accurate monthly bills.
- Additional bill data: graphs on monthly summaries (not bills) showing current period and historical energy consumption, cost and CO_2 emissions; historical consumption is sometimes detailed at the half-hour level.
- Energy efficiency advice: monthly tips sent by post, on same sheet as additional bill data, or sent to IHD, TV or online.
- TV information: personalised consumption history available via a TV Freeview box.
- Web information: personalised consumption history available online.
- IHD: shows current electricity and gas use, cost (current month and per hour), CO_2 emissions, historical data and messages from the supplier, a "traffic light" indicator of current consumption. IHD can have many different formats (e.g. touch screen).

[8] http://www.alertme.com/

[9] We do not include this study funded by ESMIG in our review because its methodology is not clear (for instance there is no information about the recruitment process).

- Usage reduction alert: IHD set up with audible alarm if consumption exceeds predefined daily level.
- Time of use tariff (TOUT): incentive to shift from peak period consumption.
- Incentive to reduce consumption: reward for year-on-year (or quarter-on-quarter) reduction in consumption.

In order to evaluate the effects of smart meter experiments, different trials without a smart meter were tested too. These are referred as 'non-smart meter experiments'.

Non-smart meter experiments

- Historical energy consumption information.
- Additional bill data: graphs on quarterly bills showing historical energy consumption information.
- Energy efficiency advice: a booklet or monthly tips sent by post and/or provided online.
- In house display: clip-on IHD showing current electricity use, cost, CO2 emissions and historical data.
- Customer engagement: monthly request for customers to read meters and provide the reading to the supplier.
- Benchmarking of the customer's consumption against the consumption of comparable households;
- Customer engagement using commitment to reduce consumption.

Each combination of instruments (i.e. each trial) has typically a size sample of 100-200 households. In some studies the different trials are organised as a progressive addition of measures, so that comparisons are easier. The table 2.1 presents a summary of the results of the 6 studies. In all studies, except in some trials by Scottish Power, consumers have agreed to get a smart meter. Overall more than 68.000 households were recruited and more than 23.000 smart meters installed. The presented data for electricity consumption reduction are taken from the best cases, as in most cases there is no observed decrease that is statistically significant.

Note that the general trend is a decrease in energy consumption[10], but this trend is visible as well in control groups (without experiment) as in trial groups, and the experiment results are generally non statistically significant except in some cases, that we detail now. This observed reduction in residential electricity consumption is difficult to relate to a specific factor, but we can guess that the numerous campaigns about the rational use of energy in the involved countries (UK, Ireland, Germany), combined with the economic crisis have yielded this effect.[11] We have also to stress that the 6 studies have been conducted in North-West Europe, and that it is difficult to generalise these results to all Europe.

[10] The real potential of energy saving is difficult to assess because it changes with time and with the progressive implementation of energy efficiency measures.

[11] Residential electricity consumption has been stabilised between 2006 and 2009 in the 3 studied countries, and has even slightly decreased in Germany, whereas it has slightly increased at the EU-15 level. See: http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/main_tables.

	Recruitment methodology	Total number of households	Number of households with a SM	Electricity consumption reduction	ToUT
EDF (EDRP)	Phone. Opt-in	1979	1879	2.3% - 4% (1)	(<10%) (2)
E.ON (EDRP)	Letter (and then phone). Opt-in	28450	8055	1.7% – 3.9% (3)	/
Scottish Power (EDRP)	Visit. Uninformed	3028	1330	No effect[12]	/
SSE (EDRP)	Different methodologies	27887	7106	2.5% - 3.6% (4)	<3%
CER (Ireland)	Letter. Opt-in	5028	3858	2.5%	8,8% (5)
Intelliekon (Germany)	Letter & phone. Opt-in	2091	1114	3.7% (6)	/

Table 2.1. Methodology and results of 6 large European studies on feedback

(1) For the most efficient combination of instruments: 4% for SM & accurate billing & IHD & energy efficiency advices (on IHD), and 2,3 % for SM & accurate billing & additional bill data & energy efficiency advices (by post).
(2) Not statistically significant.
(3) For the most efficient combination: Smart meter & monthly bills & energy advice & IHD. The most sensitive trial group is the "high use dual fuel" consumer group.
(4) 2.5% for SM, 2.9% for prepayment SM & IHD, 3.6% for SM & IHD.
(5) A specific trial DSM stimulus combining bi-monthly bill, energy usage statement and electricity monitor led to a peak shift of 11.3%.
(6) Intelliekon tested only written feedback and web portal (fed every day).

From the six scientific studies, we see that **in best cases a consumption reduction of 2-4%** can be expected in the short term[13]. This corresponds to around 15 to 30 euros saved per year for an average European household (3,500 kWh at 0,20€ per kWh). The best cases include a smart meter that is linked to an IHD (direct feedback) or to accurate billing, with energy efficiency advice. Non smart meter experiments led to no significant impact on energy consumption. An important limitation of these quantitative studies is the lack of understanding about how consumers decrease their energy use.

Each study has tried different instruments or strategies (and their combinations) and has analysed their effects on different consumer segmentations. We indicate now the most salient outcomes.

---

[12] We have excluded trials with financial incentives that have shown some effects on credit customers because we focus on information instruments only.

[13] More information about long term savings is given below.

In the case of Scottish Power no effect was found[14], and we deduce it is linked **to the way households have been recruited** in some of the trial groups: households were not informed that they were having their old meter replaced by a smart meter, to the contrary to all other trials. We come back below to this very interesting result.

The CER survey tried different time of use tariffs (TOUT). The result is interesting as it shows that **an energy consumption shift up to 10%** can be achieved (and that is in line with previous studies). This study shows also that the price difference between peak and off-peak hours is most effective beyond a given ratio (when peak price is the double of weekday price). The shift of energy consumption does not seem to increase beyond this ratio (when it is the triple for instance).

The figures presented in the table result from what has been observed after one year. Moreover, the E.ON study has analysed the energy reduction during the second year for different consumer groups. The study shows that **this reduction fades away in 2 or 3 years, except for** 2 classes of users: **fuel poor with an IHD and high use dual fuel**: (i.e. gas and electricity come from the same supplier) for all combinations of instruments with a smart meter. This is known as the **drawback effect**: "the phenomenon in which newness of a change causes people to react, but then that reaction diminishes as the newness wears off" (Wilhite and Ling 1995). The persistence of the energy reduction has therefore to be carefully assessed over a longer period than one year. And some instruments or measures should be taken to anchor new habits.

Another effect has been observed in some of the 6 studies: the **Hawthorne effect**. This phenomenon describes the situation in which the results of an experiment are not due to experimental factors, but to the fact that subjects are aware of participating in an experiment in which they are tested. When people think they are observed they have an increased motivation to achieve the task under examination. This is the case when consumers know that they participate in an experiment with new tools as a smart meter or an IHD. The consequence is that usually experiments about behaviour change yield to more optimistic results than what will be observed further at a larger scale (when this feeling of being observed is non-existent). This also could explain why the visit by an energy company employee who describes the functioning of the IHD or any other device seems to be more efficient than a distributed booklet.

To finish with the remarks about these six major studies, it is important to understand that the **size of the sample** is crucial for the (non)observation of energy savings when a feedback on energy consumption is given. The first studies on feedback have begun with small samples and have recruited the most involved users. These studies showed a large potential to achieve energy savings (10-15%). As the number of recruited users increased, the energy savings per household decreased and tended to zero for consumers who did not chose to participate. In the huge diversity of consumers it is always possible to find segments that have a positive reaction to the experiments. The first basic segment is composed of people who chose to be involved in the experiment.[15] And

[14] We have excluded trials with financial incentives that have shown some effects on credit customers because we focus on information instruments only.

[15] The response rate to the smart meter experiment invitation is rarely given in the reports. We have here an indication when Scottish Power tried to recruit candidates through a £10 reward for using less electricity than target and a prize draw: "The response rate to the pledge was 20%, which was said to be high for a Scottish Power mailing programme." (EDRP 2011, p. 22) And in the SSE study: "The initial recruitment rates for the Aware and Committed groups were between 3% and 10%." (EDRP, p. 28)

among consumers who did opt in, the 'best practices' that can be found in some places are somehow diluted.

In the following section we develop the idea that consumers should be analysed in their diversity. In the section 2.5 we expand on the notion of 'appropriation' in order to introduce new ways of tackling the issue of energy consumption. We suggest that these two concepts of diversity and appropriation explain the disappointing results of the most reliable studies on feedback.

2.4. Consumers have different levels of motivation and capabilities

A striking result of the EDRP studies consists in the fact that Scottish Power trials did not lead to any significant effect. We believe that this is mainly explained by the original recruitment methodology. Indeed households were not informed that a smart meter had been installed in their homes since it was done as a business-as-usual visit and had no opportunity to refuse postal interventions. Households were given IHDs as a normal upgrade.

This result shows that households that have not declared to be interested in devices or tips to save energy will not feel involved in the issue. EDRP analysts have examined the different studies to explore whether there is some difference between households that have opted in and those that have not. As they do not see any difference in explanatory variables (socio-demographics, localisation, attitudes, etc.), they conclude that both groups are not different. We draw a different conclusion: **the intrinsic difference between both groups resides precisely in being or not interested**.[16] The analysis shows that this interest is evenly distributed among social groups and that motivations to opt in are probably diverse. It is thus difficult to tell a priori who is willing to track one's consumption.

The motivation to play with feedback is therefore the first parameter to investigate. Similarly, we should try to figure out who are the customers not concerned by feedback since they are the majority. "The optimum target is people who have not yet taken much interest in conserving energy but who could be motivated in the process of providing an RTD [IHD] and informed how to use the device to fulfil their newfound motivation." (EDRP, p. 133) Langenheld (2010, p. 15) already stated: "there must be an – implicit or explicit – motivation: without a motivation to conserve, feedback is useless".

We have here to introduce a difference between energy consumption and energy savings: both behaviour categories are not explained by the same dynamics. Energy consumption obeys more to averages and trends, whilst energy savings are today more related to specific motivations and capabilities. Although the efficiency of electrical devices is an important factor in the electricity consumption of households, we focus here on how households consume and save electricity. The behaviour of the households can vary greatly in terms of electricity consumption. This is related to the socio-demographic variables, as the electricity consumption of a household is directly related to its income and size. Moreover, income is highly correlated to other determinants of domestic electricity consumption, as education and home ownership, and to the number of electrical appliances and their uses.

We have to note however that when people seem to belong to similar socio-demographic categories, big variations in energy consumption are observed. Morley & Hazas (2011) review the few published studies about energy use in similar contexts. Variations have been observed in the range of 1 to 3 for

[16] This is confirmed by qualitative researches. See Wallenborn & al. 2011.

electricity consumption. This obviously pleads to go beyond averages and to go deeper into practices that shape energy consumption in each household.[17]

Although energy consumption is relatively well explained by structural and socio-demographic factors (around two third of the whole household energy consumption at a global scale), it is much more difficult to explain why people conserve energy. We propose that energy savings are mainly explained by a combination of motivations and capabilities. Motivations to conserve energy can be of different orders (financial, environmental, good management, response to a new social norm, etc.), but to be effective they have to be associated to competences (understanding, experimenting, analysing, etc.).

Many studies have searched for relations between pro-environmental attitudes and energy conservation. But there is nothing conclusive, because pro-environmental attitudes are general and rather vague, and also correlated to education and then consumption (via income). This is well known as the "attitude-behaviour gap": people declare they are favourable to energy conservation but they concretely act little. This is explained by the fact that energy consumption is embodied in material infrastructure, is performed through different meanings and competences and is embedded in social interactions. However, when attitudes are specifically directed towards energy conservation, they predict behaviours better. More qualitative variations seem to explain the relation to energy, including energy conservation.

People are variably motivated to conserve energy: they can feel obliged to do so (external motivation) or they can attribute the intention to personal reasons (intrinsic motivation). Intrinsic satisfaction and a related sense of competence ('perceived behavioural control') give people a kind of pleasure that encourages them to carry on their practices (De Young 2000).

The prices of energy play an important role and are positively correlated with sustainable energy use; the higher the energy prices, the more responsive are households regarding energy savings. Most studies find that higher energy prices accelerate the diffusion of energy efficient technologies or are associated with higher expenditures for energy saving measures (Brohmann *et al.*, 2010). However, although higher energy prices are a good incentive for investments in energy-efficient technologies, an initial financial capital is required to implement these investments. Lower income households are then excluded from this incentive if they are not properly helped with other instruments.

Energy savings are easier for some consumers since it depends on their possibility to acquire energy efficient equipment. Usually two main possible strategies to conserve energy are defined: investment or behaviour change. Generally people prefer to invest in efficient equipment, — as far as they own their dwelling and have financial resources. On the other hand, tenants who are constrained to save energy will have no other choice than to change some of their practices. But beyond this very general variable, it is difficult to identify explanative variables for behaviour change.

The investment is generally a variable of action which does not seem to have a direct link with the behaviour. Therefore, the persons who are particularly attentive to their daily practices in order to save some energy are not inevitably going to make investments in this direction. Besides, certain persons who invest in materials or devices to save some energy consider that it is not necessary to change their behaviour any more.

[17] It is why the requirement of the directive EC 2006/32 will be difficult to meet: "wherever possible and useful, comparisons with an average normalised or benchmarked user of energy in the same user category". It is actually very difficult to give averages for different categories of users that would be relevant for such an analysis.

However, a positive correlation between "investments" and "behaviour" has been observed in some (owner) households (Wallenborn et al. 2006). This correlation can doubtless be explained by a strong motivation and the conviction to be able to master one's energy consumption, conviction supported in certain cases by a relative consciousness of the environmental problems. This household profile considers that to make energy savings, it is necessary to mobilize everyone in their everyday life: the energy is a subject of discussion and action within the household. This correlation between investments and behaviour is reflected in the relation to the information. The "active" persons in their behaviour with regard to the energy appear more willing to get the information concerning energy saving tricks, whereas the others are much more passive and do not pay too much attention to information.

The table 2.2 summarise the link between levels of consumption and the level of motivation and skilfulness to save energy in the perspective of potential savings. We have categorised the consumers in 3 categories: thrifty consumers who use much less electricity than the average (e.g. the two lowest deciles); extravagant[18] consumers who represent the two upper deciles of energy consumption; average consumers are the rest of households. We have chosen these terms to reflect contrasted realities, but they are not morally connoted since we do not assume any reason behind this fact. To save electricity consumers have to be motivated and capable, and we have supposed that motivation is stronger than skill for this objective.

	Extravagant consumption	Average consumption	Thrifty consumption
Motivated & capable	+++	++	+
Motivated	++	+	+/-
Capable	+	+/-	0
Neither motivated, nor capable	+/-	0	0

Table 2.2 Potential savings in different households

The table 2.2 shows where we could find consumers interested in energy saving instruments. People living in poverty are often thrifty consumers of electricity because they have few appliances. Extravagant consumers have the most potential to reduce their energy consumption in terms of absolute levels. This is however tempered with the capabilities (knowledge, skill, money) to act. We can nonetheless wonder whether the first case (extravagant consumption with motivation and skilfulness) is not void. Indeed we can assume that the consumers who are motivated and capable to save electricity have already reduced their consumption. Nonetheless the table is quite in line with what is presented as the ideal in the mainstream model. In conclusion the most potentially interested consumers are 1) extravagant and motivated, and 2) average, motivated and capable.

To be complete, a third dimension should be added to consumption and motivation: lifestyles. This dimension is crucial to understand why policy instruments are diversely adapted to households. Lifestyle is a fuzzy word that captures both people's habits and the social meanings they give to their habits. Electricity consumption is embedded in routines and habits: electricity in itself has no clear meaning from a consumer's perspective. The meaning people can give to their electricity

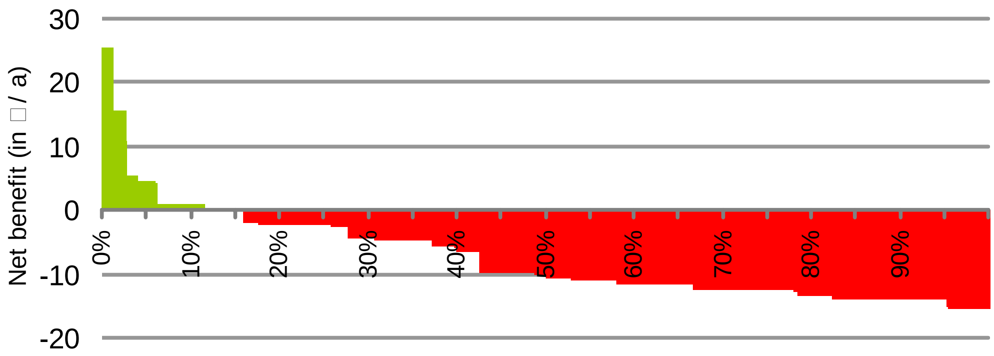
[18] Extravagant means 'lacking restraint in spending money or using resources'.

consumption or saving is linked to the way they live. The search for time, comfort and convenience seems decisive to the households' energy consumption, independent of economic or environmental concern (Anker-Nilssen, 2003).

This third dimension is however difficult to represent on a graph because, contrary to the two others, there is no ordinal scale to classify lifestyles, neither is there a clear segmentation of lifestyles. Yet, to be effective, instruments aimed at changing electricity consumption patterns have to integrate the diversity of lifestyles. Effective instruments are those which can move consumers one cell up and right on the table 2.2

To our knowledge there is almost no study that considers the diversity of consumers when assessing the energy saving potential. Fortunately, Frontier Economics has developed a model based on 200 different types of households in order to assess for which consumers smart meters would be financially beneficial (Frontier Economics 2011). The differentiation is made according to the expected energy saving potential through different characteristics of the households: size of the dwelling, number of persons, electricity consumption, affinity for technologies, readiness to use a smart meter. The big interest of this model is to take into account the diversity of consumers, not only regarding consumption but also regarding motivation and skilfulness.

One of the main results of this study is presented in figure 2.1 that shows the net benefits (i.e. benefits after deducting installations and operational costs) per household in the case of a mandatory rollout of smart meters in German households. About 15% of households would benefit from this measure (green zone) whereas it would be detrimental for the others (red zone).



Source: Frontier Economics.

Figure 2.1 Distribution of the net benefit of obligatory installation of a smart meter for German households

The total benefit of the operation is negative, despite the economies of scale resulting from a nationwide installation. The benefit is however positive in two other cases:

- obligatory installation for consumers that have a yearly consumption above 5,000 kWh;
- smart meters are deployed on a voluntary basis and 20% of households opt in.

In conclusion, this study supports the recommendation to deploy smart meters on a voluntary basis (or in targeting 'extravagant' consumers). Moreover an optional installation of smart meters will foster the development of new instruments to raise motivations and skills of consumers, as we show in the next section. And if extravagant consumers are first enrolled, that could entail a domino effect towards a new social norm.

2.5. Appropriation and domestication of smart meters

To understand why the potential energy savings are far from being achieved (through an in-home display or any other instrument), we have to acknowledge 1) the big variety of consumers, 2) the fact that the appropriation of a new instrument takes time and follows unpredictable patterns.

When the multitude of users is not taken into account (cf. the recruitment methodologies), it is not possible to notice that the majority of households have much more difficulties to save energy than the ones who are willing to do it. The motivation to "play" with a new technology is determinant in the use of feedback. Furthermore it requires enough knowledge, time and other capabilities. But who wants to play with new toys and games? What is the meaning of "engaging consumers in managing energy" (Ehrhardt & al. 2010, p. 36)? How to interest people in energy issues?

Studies about displays show that IHD are much more efficient when combined with other instruments. Given the plurality of household types and the multitude of their practices, we can assume that different combinations work differently according to different profiles. This implies that policies should not focus on only one strategy — search for the most efficient combination — that would reflect a global average, but instead foster different ways to tackle the issue.

The analysis of the E.ON study (EDRP 2011) reveals that learning curves (and drawback effect) are different according to social groups. The difference in appropriation of a new tool is easily explained in terms of diverse motivations and capabilities. The integration of a new appliance into current household practices is not straightforward. To be correctly used, instruments have to be appropriated, i.e. contextualised in daily routines. The 'appropriation' concept is used to describe how users integrate the objects in their lives, households or network. They integrate objects into an existing network of objects, practices and meanings. It suggests that persons are affected by the objects that they integrate in their lives. This interaction between consumers and products is reciprocal and at the basis of the coevolution between technology and its social use: technology is produced and stabilised only if it is integrated into social practices. Objects can change the time schedule of the family, it can change the way users interact, can modify their symbolic network, and so on.

Energy savings instruments should be conceived with an evolutionary perspective (Foxon 2011). Technology, capabilities and motivations (i.e. meanings given to new practices) are in a process of co-evolution. The coevolution of objects and usages implies that practices follow a certain trajectory, that practices are 'path-dependent'[19] (Pred 1981). Individuals carry out practices that take time and place. Individuals are constrained by finite time resources, by the impossibility of simultaneous participation in spatially separated activities and by the time involved in moving through space. For example, Bladh (2010) interprets (electric) lighting use as a kind of path dependence. The individually chosen lighting that is used and the past experiences of lighting are important elements when new lamps are purchased: history matters when new lamps are chosen. We believe that the appropriation of smart meters, IHD and other instruments depends also on the consumer's past experiences. The domestication of new technologies requires several 'trials' in order to be adopted (Lehtonen 2003).

[19] Path dependency refers to a term from systems analysis describing persistent differences in development paths resulting from differences in initial conditions and determining factors (e.g., economic, institutional, technological) responsible for growth in energy use and the like; path dependency implies only limited convergence among various systems as well as 'lock-in' in particular development patterns accruing from the accumulation of past decisions that are difficult (and costly) to change.

The ideas of appropriation and domestication challenge the basic assumption that a technology 'penetrates' a market, by being adopted first by small groups and then spreading to more and more people, before reaching a mass-market stage. In the 'penetration theory', the consumer is given only the power to adopt or reject a technology, because this theory is focused on the purchase moment. In the 'domestication theory', the consumer has a more active role in the adoption of new technologies. At an early stage of their life, products undergo different trials by different groups of people, and the life of the object in households has different phases. Different kinds of trials may happen: some are concerned with the compatibility of the object with other things and with people; others are concerned with attachment and quality. These trials are also important as they produce knowledge on the uses, and they are part of the new uses adopted by households. If we take seriously the idea of consumers as competent practitioners, and if they are allowed to experiment different tools and to give new meanings to 'energy', they will be more active and engage towards energy management.

There are two main roads to foster the appropriation of energy saving instruments by consumers: 1) improve existing feedback devices; 2) make energy consumption a public issue through the implementation of new instruments.

Let us look first at **feedback devices**. How does a smart meter enable users to change their energy consumption? What can a SM technically do on daily practices? Interpreting aggregated electricity consumption is difficult. The aggregation happens both at space and time scales, and that makes it laborious to associate consumption to daily practices. Even if feedback was given for each appliance, it would require clear benchmarks to compare to other appliances in the home or to the most efficient on the market.

Displays need to be explained: how to read and use the information is not given at once. "*Quality matters*: information needs to be clear, easily seen amongst other material sent by suppliers, and presented in an attractive way. It also needs to be relevant and timely (e.g. appropriate to the season) and kept up to date as the options for action change (e.g. because of new technology or incentives). The design of RTDs [IHDs] and the explanation of how to use them are similarly essential to effective customer engagement, satisfaction and savings. *Quantity also matters:* a balance needs to be struck between providing sufficient information and avoiding information overload. For example, regular small nuggets of information appear to be more effective than a single delivery of comprehensive information (to provide information in manageable amounts and to maintain behaviour change prompts over an extended period)." (EDRP 2011, p. 7-8)

These recommendations (and others) are wholly relevant, but we would like to go further in the involvement of consumers. Indeed users can participate at an early stage in the design of devices they will use. User involvement in design is advised because it can help to improve the product and its usages. Current feedback devices, IHDs and other instruments meet only a small part of consumers. We suggest that consumers' interests and needs will be more satisfied if consumers can be involved in the design of the instruments. However, to grasp the full promise of this proposition we have to depart from the idea that objects are neutral. We want to design instruments that will have an effect on consumers, and that already embody some kind of moral norm (Verbeeck 2005).

When objects are designed, they are infused with the description of the user's behaviour. But more than that, objects are designed to allow certain behaviours and counter others. "Scripts are the structural features of artefacts encouraging certain user actions while counteracting others" (Jelsma 2003). Scripts have a prescriptive force that steers users in a certain direction. To embed a script in an artefact, designers need to have a certain idea of the target users they have in mind. So they cannot cover everything that the user could do; only what they can think of. Therefore the scripts embody socio-cultural conventions. Scripts do not achieve that in a single way however: not only do the scripts embed socially acceptable practices, but the scripts also influence what is accepted or done in a given society.

Users may have different kinds of responses to the scripts. Some can accept them, ignore them, develop "anti-program" designed to trick or fake the script, and so on. It is impossible to know how a script will be appropriated. We consequently propose to multiply experiments that leave the feedback scripts open and allow users to co-elaborate new solutions. That entails also that ***consumers should always have access to their own data***.

Beyond the improvement of current feedback devices, the second strategy is to make energy consumption a public issue through the implementation of new policy instruments that change the frame of energy so that energy saving tools acquire new meanings. Ideally, energy savings can be made a public issue where energy is publicly consumed, as in education and work places. This strategy entails creating new situations where a co-evolution of instruments and meanings is explicitly intended through learning processes. Experimenting allows escaping from the tyranny of figures and quantification. If we want to turn to more 'qualitative', sustainable things and practices enhancing the wellbeing of consumers, we also need policies that dare considering qualities without being obsessed by quantitative evaluations and the reduction of economic figures.

Smart meters are sometimes presented as the new "game", and compared to what happened with mobile phones and the Internet. But here the game is saving electricity, not providing a new service with a multitude of new possibilities. Therefore it is needed to create a real interest for electricity and energy saving in general first. We can notice today the emergence of a new social norm: energy saving. How could this social norm be extended and given new meanings in practices?

Social norms and individual attitudes can conflict. Conflicts, debates and controversies are what make a social norm apparent: when an individual is stigmatised for not following a rule, this rule generally implies a social norm, i.e. a good way to behave. Household energy saving is an emergent social norm. But individuals struggle to conform to or to escape from the new social norm. This is also true in households where many conflicts have been reported through qualitative studies. Half of the individuals state that "in [their] family [they] sometimes disagree on the indoor temperature." (Wallenborn et al. 2006). Households are compound of different individuals who have different levels of motivation and various hierarchies of norms.

One way to extend the social norm is to use rewards for "good behaviours" (e.g. incentives not necessarily financial). Policy measures should however go beyond information and rewards to individuals. Rewards are not always the most effective way to convince consumers: loss aversion is often more powerful than gain expectation (Kahneman & Tversky 1979). Community engagement can also be an effective tool, making use of social relations and networks, and moving social norms away from acceptance of energy wastage. It may, however, require a higher initial investment and will not necessarily work in all localities. Local support from a combination of experts and peers can help consumers understand what to do, appreciate reasons for taking action (reasons that make sense to them personally) and provide the resources (time, space and money) necessary to take action. We think that to increase the number of 'active consumers' towards smart meters, the general framing of energy has to change. This can be done by implementing new policy instruments. What follows is a non-exhaustive list of ideas:

- Progressive tariffs. Extravagant consumers are advantaged nowadays: the more they consume, the cheaper the additional unit of electricity. Progressive tariffs reverse this logic and reward thrifty consumers. To the extent that access to energy is a right, electricity consumption corresponding to the basic needs should be delivered at a low price possibly financed by those that consume well beyond the average. Beyond a given threshold (or multiple thresholds) the kWh price should steeply increase. This kind of progressive tariff exists already for electricity and water in some European regions. We think that this new tariff could contribute to progressively change the perception of energy from an infinitely available resource to a rare and precious good.

- Complementary currencies allow incentivising users with other units than money (Euros). This instrument has already shown its capacity to modify consumer behaviour in various commercial projects (e.g. loyalty points, frequent flyer programs, etc.) and researches on using it for energy savings are on-going[20]. Such units, or points, can be much more motivating than their financial equivalent depending on the way they have been designed. Moreover, if adequate rewards are defined (e.g. privileges, access to special events), beyond user motivations, these 'currencies' can actively contribute to both the establishment of new social norms and the reduction of the rebound effect.

- Personal carbon trading (PCT) "is a general term used to describe a variety of downstream cap-and-trade policies, which locate rights and responsibilities for the carbon emissions from household energy use and/or personal travel at the individual level. […] PCT is markedly different from current policies covering individual energy use and carbon emissions, which often operate at a distance from individuals (e.g. obligations on energy suppliers), do not require their direct involvement (e.g. minimum efficiency standards for products), and fail to communicate the significance of different decisions on personal carbon emissions. PCT is not envisaged as replacing most current policy, but rather as an enabling policy which encourages individuals to make the most of existing schemes such as product and building standards, energy labels, and taxation and financial incentives." (Fawcett & Parag 2010, p. 329) If a PCT scheme was developed, smart meters would certainly get new significations.

- Smart cities is still an elusive concept but it rests upon the idea that investment in innovative solutions could improve the quality of life in urban areas as well as the efficiency of infrastructure and services. ICT would help to develop greener and more inclusive economies. Living in such an environment can only foster the desire to use devices as smart meters. At a smaller level, eco-neighbourhoods are places where energy consumption takes new meanings.

In conclusion, smart meters are not instruments that deliver energy savings by themselves. Even with advanced functions as an IHD, consumers who are not already minimally interested by energy issues do not appropriate smart meters. It is therefore crucial to change the frame in which smart meters could get new meanings. Similarly, the instrument mix must not be based only on information and economy because it will permit to link the saving energy social norm to different dimensions of consumers' practices. Other new norms will emerge and smart meters can contribute to that. But the way to use smart meters should remain as open as possible to allow the development of new meanings and motivations.

[20] See for example the INESPO project (www.inespo.be).

2.6. How will consumers become 'active'?

We have seen that current systems of feedback associated with smart meters can yield to a reduction of 2-4% of electricity consumption when consumers have opted for its use. No effect is observed when smart meters are installed without the explicit agreement of consumers. And the vast majority of consumers are today probably not interested in any kind of feedback. In conclusion, without a prior motivation to save energy, feedback is useless. Besides motivation, capabilities such as knowledge, money and skills are important factors to appropriate effectively feedback and accordingly change energy-using habits. As many experiences show a 'drawback' effect, the motivation towards energy savings must be frequently restored. But the sole presence of an IHD is not enough to maintain the attention.

An obligatory smart meter rollout is therefore not advised. We have however identified two potential groups of consumers that could benefit from customised toolkits based on feedback: 1) extravagant and motivated, 2) average users of energy but motivated and capable to conserve. Some trials show that fuel poor consumers could also be interested by an IHD but this case has to be considered cautiously because this must not increase the total price of electricity and particular attention must be paid to the instructions and user guide[21].

Future cost-benefit analyses should therefore be undertaken taking into consideration different consumer profiles. When CBA are based on average consumers, they blur important differences and can be detrimental to already thrifty consumers, including low-income households.

In the first chapter we have argued in favour of a flexible smart meter solution in order to avoid lock-ins and to open future possibilities. In this chapter the argument of flexibility is reinforced by the need to meet the high diversity of consumers. Beyond the simple choice to opt out or not, the different levels of consumer motivations and capabilities require a variety of feedbacks and other instruments. Smart meters are devices that call for new skills whereas their domestication process is not necessarily fun. As we do not know how people save energy with feedback, it is decisive to create situations where consumers can learn what to do with different interfaces and can share what they have learnt. We can guess that we are only at the beginning of feedback devices and of the ways to give them meanings. The theory of domestication suggests letting users try and adjust a product which is at an early stage of its development — as feedback devices are. Acknowledging consumers as truly active entails that they could take part in the construction of the solution. A direct recommendation is then to allow consumers to have unrestricted access to their own consumption data.

Besides the improvement of feedback interfaces, it is also necessary to change the way the energy issue is framed. Beyond information towards individuals, many more policy instruments can and should give new interests to energy savings while respecting consumer heterogeneity (including fuel poor households). Of course if consumer awareness of energy consumption is raised, in parallel to a deepening domestication of the smart meters, we can foresee that new questions will arise. If 'energy literacy' increases in parallel to the understanding about direct consumption, consumers will probably begin to ask inconvenient questions: what should we do with embodied energy, associated consumption (e.g. ICT servers) or other sectors (industry, transport)?

[21] Besides smart meters, audits are the other instrument encouraged by the Energy Efficiency directive proposal towards residential consumers (COM 2011/370, article 7). We think that most of these remarks about the limits of current feedback use through smart meters can be repeated for personal audits.

Smart Metering features

This chapter aims at understanding the link between the main expected functionalities of the smart meters, their consequences in technical terms and the way they are related to the main actors of the electricity market.

3.1. Who needs what service?

The overall discussion on the functionalities of the smart meters is complex because we are in presence of a split-incentive problem. The different energy market actors favour the deployment of smart meters for various reasons. Ideally the costs of such a system should be distributed according to the expected benefits of each actor but such benefits are almost impossible to evaluate with sufficient precision.

One of the major points of disagreement is about the benefits that smart meters can bring to the households. In particular, no clear scientific agreement can be found on the expected energy savings that can be achieved with smart meters in an average household, as such an "average consumer" does not exist (see section 2.4).

Moreover, estimating the overall cost of an advanced metering infrastructure and allocating them amongst the actors is a difficult exercise for two reasons: the costs are very dependent on the functionalities that are to be implemented and the view on how the system will evolve; the benefits are shared by all actors and are also dependent on these functionalities.

Therefore if the "optimal" solution is left in the hands of the market, it will lead to an unfair negotiation between actors with unequal weight and influence capabilities. Indeed, replacing all existing meters by smart ones represents a market of about €40 billion in Europe. To this amount the costs of other components of the smart grid infrastructure must be added, reaching a total of around €500 billion for the whole energy network.

Not surprisingly, the manufacturers are pushing hard to get the infrastructure deployed with the most complete set of functionalities[22]. But the question remains: who will pay and who will benefit from which added service?

To solve this tricky problem, we propose to classify the functionalities with respect to the needs of the different actors and suggest a modular solution for which each actor would finance his part. For this purpose, we avoid speaking in terms of devices, and rather use the term service. Hereunder we review the different possible services and conclude each analysis by a short technical impact appraisal and a discussion on the envisaged service.

3.1.1 Monthly billing

As energy billing seems beyond discussion, data must be transferred from the meter to the supplier. We differentiate here billing from invoicing. The bill is the statement of account, accurate information that the consumer receives. The invoice is the request for payment. With smart meters, consumers should receive accurate bills but should have the right to decide if they want to pay their exact monthly consumption (which can significantly vary from month to month) or a fixed amount.

---

[22] For example energy savings estimated by the study financed by ESMIG is about the double of those estimated by scientific literature.

Today, in some countries, consumers don't know how much energy they use because of a lack of installed meters and in most places information is available only once a year. For these households, there is no obvious perceived relation between what is consumed and what is requested on the intermediate invoices. A monthly bill provides the consumer with such this relation but is also closer to usual payment practices (e.g. like in the telecom sector).

Whilst the different actors agree with the requirement to provide accurate consumption information to the consumers, some confusion still exists around article 13 of the Energy Services Directive (2006/32) about the information on the actual time of use. This article states: "Member States shall ensure that, in so far as it is technically possible, financially reasonable and proportionate in relation to the potential energy savings, final customers for electricity, natural gas, district heating and/or cooling and domestic hot water are provided with competitively priced individual meters that accurately reflect the final customer's actual energy consumption and that provide information on actual time of use." And: "billing on the basis of actual consumption shall be performed frequently enough to enable customers to regulate their own energy consumption."

Member States have different opinions about the meanings of "actual time of use" and "frequently enough". Some interpret the requirement as the necessity to provide individual meters to the consumers. Other Member States believe that the directive should lead to smart meters and monthly bills (Renner & Martins 2010). We therefore consider that the basic service a smart meter can provide is a monthly bill. We examine below (3.1.3) how the new directive proposal recasts this requirement.

Technical impact:

As the amount of data to achieve this service is low (a few kilobytes per month) and does not need to be sent in real time[23], the communication infrastructure and related costs can remain very low. The Italian smart meter deployment, based on the SITRED standard (initially private to ENEL, but now opened to the market) shows the technical feasibility of such a system — and demonstrates its economic benefits in regions where fraud is estimated to be high.

Discussion:

The operational costs of the metering companies are significantly reduced by a remote reading of the meters as it does not require physical displacement of an agent anymore. Moreover, errors are expected to diminish and related costs reduced. The suppliers will also benefit from more frequent knowledge on households consumption and will reduce risks and complaints about estimated invoices. Consumers will benefit from an accurate feedback of their monthly consumption. However, if this service entails a general increase of the energy bill, all consumers who cannot compensate this by a decrease of electricity consumption will lose money. These consumers include those who are already thrifty, e.g. most of the low income households. We also have to remind the direct interests of meter and/or smart grid manufacturers in the deployments of such systems.

3.1.2 Real-time feedback

As we have seen in section 2.2, most studies on smart meters expect households to achieve energy savings thanks to the feedback provided either through accurate consumption data on a monthly basis (e.g. through billing, see point 3.1.1) or by real-time feedback.

[23] Communication within a few hours or once a day could be sufficient.

The latter is typically linked to in-house displays (IHD) or web-based services. The service here considered is thus a real-time feedback on electricity consumption that includes precise historical consumption data. The way this data is presented to consumers is crucial.

Though real-time feedback may improve energy-awareness, not all households require this service (see section 2.3). Moreover, different households have different expectations of the type of device and/or service required: basic or advanced real-time consumption monitor; disaggregated energy consumption per appliance, application or room; monitoring for security reasons; more comprehensive advice on energy savings.

Technical impact:

As real-time feedback can be provided directly by the smart meter, there is no need for communication outside the household. However, the service will generally require an IHD and a communication channel between the smart meter and the IHD needs to be set up. When an existing Home Area Network (HAN) is already available (typically all households having a Wi-Fi-enabled router for Internet access), the installation costs can remain low.

Discussion:

Real-time feedback systems such as IHDs can be great for motivated customers with sufficient skills and for the technologically savvy but probably have a quite limited effect on the majority of consumers. The KEMA (2009) cost benefit analysis for the Brussels Region estimated that the additional savings that can be related to direct feedback (such as IHDs) is 0,44% in average.

If the business model remains unchanged (revenue is currently proportional to the amount of consumed kWh), DSO and suppliers have no direct interest is such a solution, especially as these devices can bring an additional burden in the hot-line.

3.1.3 Historical consumption day by day

The requirement of the Energy Service Directive (2006/32/CE) about a "frequently enough" billing is clarified in the proposal for an Energy Efficiency Directive (COM 2011/370) as the following: "Member States shall ensure that final customers for electricity, natural gas, district heating or cooling and district-supplied domestic hot water are provided with individual meters that accurately measure and allow to make available their actual energy consumption and provide information on actual time of use, in accordance with Annex VI." The Annex VI describes very precisely what a smart meter should deliver:

"The private data exported through the interface shall offer the final customer a possibility to consult his/her historical consumption levels (in local currency and in kWh, kJ or m3):

a) in the last seven days, day by day;
b) in the last complete week;
c) in the last complete month;
d) in the same complete month the previous year;
e) in the last complete year.

The historical periods shall match the billing periods for consistency with household bills."

This requirement is based on the idea that consumers are able to compare their consumption on a daily basis along a cycle of one week. Consumers are assumed to remember what they have done each day of a week and hence learn which activities consume more or less energy. The service here provided is somehow between the monthly bill (3.1.1) and the real-time feedback (3.1.2).

If this service was implemented by the DSO or the supplier, it would involve a daily collection of consumption data that goes beyond what has been achieved in most existing smart meter deployments. In the two European countries where a smart meter rollout has been achieved (Italy and Sweden), the billing is monthly. And this frequency has repeatedly been estimated as "enough", as the different experiments in the EU show (see section 2.3).

However, no guidelines are given about the implementation of such historical data and two possibilities can be envisaged: historical data can be stored locally (e.g. in the smart meter itself or in an IHD) or in the database of the MDM (cf. section 1.4), which makes a significant difference regarding the communication and data storage infrastructure. In any case, the aggregated consumption should not be sent to the DSO more than once a month, unless requested by the consumer.

From the consumer's perspective, historical data should be stored locally as it simplifies privacy issues, reduces transmission infrastructure and costs. Moreover, article 8 of the energy efficiency proposal affirms that this service "shall be provided to final customers free of charge" and such local storage will certainly be cheaper to deploy.

3.1.4 Personalised consumption advice

Monthly billing, feedback devices and historical consumption are services that can help consumers to increase their awareness of energy consumption and induce some electricity savings in the range 0% to 4%, as seen in section 2.3. However, as indicated by Darby (2006), better results can be obtained by providing customised advice related to their consumption patterns. This can be done by auditors coming to analyse the bills and checking throughout the households what can be done in order to reduce consumption.

Smart meters can provide a new support for this. Indeed, from a detailed load curve measured at the level of the main household meter, it is now possible to disaggregate the total energy consumption into individual appliance consumptions[24] and provide personalised advice in relation with the appliances that are used by the household[25]. This process can be performed either within the smart meter or externally, for example by the utility or by an Energy Service Company (ESCO).

Technical impact:

Externalising such a service requires exporting large amounts of data, but this data flow can be entirely separated from the billing service and make use of the households' existing ICT infrastructure, such as the internet connection, for example. If such service is performed within the meter or by an additional in-house device, there is no impact of the network infrastructure or on the DSO's or supplier's business.

Discussion:

These services are mainly in the interest of consumers and of ESCos willing to provide such new services to households. If ESCos remain free to contract directly with consumers, a new market of household oriented ESCos can emerge. To achieve this, households must retain the legal and technical means to send their consumption data to such an ESCo, should they want to.

[24] This technique is called Non Intrusive Load Monitoring (NILM).

[25] For example, see the Energy Consumption Advisor project: http://energyconsumptionadvisor.eu/.

3.1.5 Meter management

Besides remote reading, DSOs and suppliers may be interested in additional functionalities of the smart meters that contribute to remotely manage the meters and their relation with the customers. This is essentially related to the remote enabling/disabling of the meters and to the remote setting of the maximum power of the meter.

Technical impact:

As for monthly billing, this service only requires a small amount of data (a few kilobytes on request) and is not time critical[26]. The communication infrastructure and related costs can remain low.

Discussion:

Remote enabling/disabling and maximum power setting are clear advantages of smart meter infrastructures. Indeed, consumers get a faster service when moving in and DSOs can react faster and spare workforce, as physical displacement is not required for such operations anymore.

However, the usage of these features should be controlled by a regulator, as this type of service can provide suppliers or DSO with excessive means to put pressure on customers (e.g. in case of unpaid invoices, disagreements, errors). The evaluation of such potential pressure has been evaluated to 1.70€ per connection and per year in Flanders (KEMA 2008).

3.1.6 Network management

Smart meters can provide useful data for the DSOs to achieve the mission of supplying consumers with electricity at a minimum quality (Directive 2009/72). The smart meter is here seen as a remote measurement tool to achieve a better understanding on the network load and status.

Active power consumption, but also reactive power, voltage, or other quality parameters can be gathered through smart meters. Moreover, information on power production from CHP, PV or other existing or future distributed sources (including electrical vehicles) is also helpful to manage the network.

Technical impact:

The type of information required for the management depends on the topology of the network, the type of loads, the presence of distributed generation (e.g. photovoltaic) and many other parameters that are outside the scope of this assessment. However, data can roughly be categorised in two groups: real-time information for the direct management of the network (smart grid features) and monitoring information, less time-critical, used for analysing energy flows or incidents and to manage the network on a longer term (capacity planning). Detailed quarter-hourly measured load curves can be useful for those missions. DSOs are therefore interested in deploying an advanced metering infrastructure that offers such capabilities.

It should however be pointed out that, for this sole purpose, it is not necessary to have a measuring point in each household. Making measurements for groups of households, on the same distribution cable (feeder) or in large buildings is in most cases enough.

Discussion:

From the network management viewpoint, the distinction between smart meter and smart grid is blurred. Is the smart meter part of the smart grid (in which case additional measurement and

[26] Communication within a few hours or once a day could be sufficient.

communication features should be included) or should it only be considered as a component of the billing and feedback system for consumers?

What seems certain, however, is that the additional costs (extra features in the smart meter, communication infrastructure with high bandwidth, network management tools, etc.) should be separately assessed as costs are related to the power supply quality only, not as part of the metering service. Indeed, from the consumer's perspective, these features have no direct benefits and are totally decoupled from the energy saving concept.

3.1.7 Advanced tariffs and payment methods

Conventional meters generally have one or two registers, which basically support two types of tariffs: the flat fee and day-night tariff. Smart meters can offer, at almost no extra costs, the possibility to manage a large number of registers, opening the possibility of offering many new kinds of tariff schemes, such as, but not limited to:

- Time-of-use pricing (ToU) is merely an extension of the day-night logic and simply introduces a predefined set of time periods with different prices for each period.
- Dynamic pricing or real-time pricing refers to systems where the actual price of the electricity varies in relation to the wholesale market price.
- Critical peak pricing (CPP) refers to an intermediate tariff scheme which is mainly a ToU system but where a higher price can be charged on certain peak moments.

Besides the pricing itself, the payment scheme is also important for the consumer. Like in the telecom market, electricity may be paid after receiving the bill (postpayment) or in advance (prepayment). Presently, changing from one payment mode to the other generally involves the costly physical changing of the meter itself. Smart meters can now allow for the remote switching between prepayment and postpayment.

Technical impact:

Remotely changing the payment method, defining ToU tariffs and to some extent implementing CPP is not too problematic as they do not require large amounts of data to be transferred and timing is not a big issue. This is not the case for dynamic pricing where data transfer and monitoring of the system can become problematic.

Discussion:

From the supplier's viewpoint, new pricing and the ability to switch remotely between postpayment and prepayment are major advantages. They can propose complex tariff schemes that reduce their commercial risks or increase their competitiveness on the market. However, we can fear that, as what happened in the telecom market, tariffs become too complex for customers to effectively compare different offers. Furthermore, most of energy consuming activities cannot be shifted as easily as delaying a telephone call.

From the user's perspective, such a service also requires a special attention with regards to the customer's protection. Indeed, low income households could be gently forced to adopt prepayment meters. Whereas prepayment may be useful for some households, energy units are generally more expensive than in the other contract types. Prepayment methods and pricing must therefore be regulated. On the other hand, prepayment implies regular reloading and thus increases energy consumption awareness and is therefore sometimes promoted as an energy saving tool, although it can also be a comfort reduction tool.

3.1.8 Demand-response

Integrating more renewable energy sources (RES) slowly changes the relation between consumption and production. Indeed, the old paradigm of adapting production capacity to the actual consumption needs to be changed as more intermittent renewable energy sources, such as sun and wind, are deployed. Demand-response is part of the solution as it allows bringing part of the electricity demand to follow the production capacity. This includes two aspects:

- Reducing the consumption when production is limited, either by shifting the moment the load is used.
- Increasing consumption when there is an excess of production. Here is where energy storage comes into play.

Demand-response is essentially part of the “smart grid”, but as user behaviour and household appliances can significantly affect the global load curve, the idea is to use the smart meter as a gateway to get a “signal” that reflects the state of the electricity production into the household. This signal can be financial (e.g. by using dynamic pricing) or a remote control (e.g. remote control of some load in the household).

In households, only a fraction of electricity consumption can be shifted[27] and this fraction increases with the consumption, the size of the house and the capacity to invest in automation. Different strategies are possible: shifting consumption time from peak hours to off-peak hours (washing machines, dryer); storing energy in freezers (by allowing them to lower their temperature far below -18°C) or in water boilers so they can be switched off at peak hours; electric vehicles can also play an important role.

Technical impact:

From the communication point of view (household-DSO link), this service requires more frequent data exchanges (according to the grid conditions) and response times typically within one hour. The main issue, however, is how the signal will be defined and by which actor. Will it be based on technical indicators of the grid (e.g. RES) or on economical indicators (e.g. wholesale market pricing)? Or a combination thereof?

Discussion:

As, to our knowledge, there is no clear architecture and methods agreed upon, we can expect the different market actors to influence the future smart grid architecture in a way that bests suits their interests. From the household perspective, however, demand-response can only be done in two ways: manually or automated. The latter will require new investments in smart appliances that can correctly react on the grid signal. We expect that only a fraction of the households would be interested by such a service.

3.1.9 Summary

The analysis of the eight categories of services that can be brought by smart meters is summarised in table 3.1. We consider that the first three services should be provided free of charge to consumers: monthly billing, real-time feedback & advice, historical consumption day by day.

[27] See Smart-A project (www.smart-a.org).

The fourth service, personalised consumption advice, could be delivered and invoiced by external companies such as ESCos. This service set designates, among others, advanced feedback (disaggregated consumption) and customised advice.

The other analysed functionalities, services 5 to 8, meet the particular interests of other actors, not consumers, and have been described in the preceding sections.

Along our discussion in section 2, we have divided households in 3 categories: thrifty consumers who use much less electricity than the average (e.g. the two lowest deciles); extravagant consumers who represent the two upper deciles of energy consumption; average consumers are the rest of households. Let us remind that the threshold of the 2 (lower and upper) deciles is indicative and that the terms used are descriptive as they do not carry any moral meaning. We also look at the interests of other actors in the potential functionalities: distribution system operators (DSO), electricity suppliers (Suppl.), energy service companies (ESCo). Let us remind that other non-mentioned actors have also interests in the smart meters, e.g. smart meter producers, telecom companies, TSO.

In the table the plus (+) and minus (-) indicate the strength of interest of a given actor in the analysed service. This is a qualitative scale, built by contrast of interest for the given service. Therefore this table should be read line by line. The comparison of different services for a given actor is here less relevant.

The overall analysis has been made without taking into account the costs of the smart meter infrastructure (as we have no vision on how these costs will finally be split between consumers and the other energy actors) and assuming that there is no general increase of the electricity price due to smart meter rollout and to the development of the smart grid.

		Thrifty	Avg	Extrav	DSO	Suppl.	ESCo
1	Monthly Billing (free)	++	++	++	++	++	
2	Real-time feedback (free)	+	++	+++	-	-	
3	Historical feedback at a daily scale (free)	+	++	+++			
4	Personalised consumption advice (ESCo service)	+	++	+++			++
5	Meter management	+/-	+/-	+/-	+++	++	
6	Network management	(+)	(+)	(+)	++	++	
7	Advanced tariffs and payment methods	-	+/-	+		+++	
8	Demand response	-	+/-	+	++	+++	++

Table 3.1 Benefits and disadvantages of the different smart meter services in regards with the different actors

<u>Monthly billing</u> is an information service. It requires typically a few kB per month – low bandwidth infrastructure. It is supposed to benefit all consumers as long as they can still pay constant invoices across the seasons during one full year. The effect of only such a monthly billing may allow users to achieve a very limited amount of energy savings, typically between 0 and 2%. This service also allows a better follow-up of the customers by the suppliers and helps DSOs to better detect fraud and errors.

Real-time feedback is a service that helps motivated and curious customers to increase their awareness and knowledge of their consumption and hence can help achieving savings. Its cost remains low because such a service can be achieved without any outbound communication.

Historical feedback at a daily scale is the service suggested by the directive proposal (COM 2011/370). As for real-time feedback, this service can be provided locally by the smart meter or by an IHD and should not have any impact of the smart meter infrastructure.

Personalised consumption advice will certainly develop in the coming years if the market for such services remains open (ESCo market). Higher bandwidths are necessary but the household's existing internet access can be used as this service is non critical. This service will mostly serve extravagant users.

Meter management is especially interesting for the DSO and the suppliers as it reduces operational costs and helps fraud and leakages detection. Consumers also benefit from these services as it eases supplier change (switching) and moving-in/moving-out, but at the price of exposing a new threat for security of supply (security issue) and providing suppliers with a means of putting pressure on customers in case of disputes or unpaid invoices which can be considered as a threat for low income households.

Network management requires adding measurements and almost real-time communication capacities to the smart meter. This service is necessary when the smart meter is considered as part of the smart grid infrastructure. It mainly benefits the DSO and the suppliers and consumers only indirectly, considering the fact that it contributes to the quality of supply. On the other hand, it raises questions regarding data privacy and security.

Advanced tariffs and payment methods allow new business models to be created. However, they should be considered as a potential threat for low-income households. This topic relates to energy poverty, "vulnerable consumers" and "public service obligations" and should therefore be taken into consideration by Member States. From the smart meter's viewpoint, we suggest that these functionalities be included in the smart meter, free of charge for consumers. Moreover, we stress that the switching from post payment to prepayment methods should require the intervention of an independent third party (beside the consumer and the supplier). National energy regulators must define procedures in which the consumer has always the right to appeal before a change in their energy provision.

Demand-response is today's solution to the increasing share of intermittent renewable energy production in our networks, even though there is no clear or agreed vision of what signal must be generated (price or status of the grid) and what entity will be entitled to generate it. Nevertheless we must keep in mind that low-income households will most likely not have sufficient investment capacity to benefit from such systems that require the replacement of old appliances by smarter ones. On the longer term, however, we must keep in mind that possible breakthroughs in energy storage technologies could elegantly solve the demand-response issue.

3.2 A modular architecture for all drivers and actors

We have seen that the services and functionalities of smart meters correspond to different expectations from consumers. Furthermore, consumers should not be considered as a homogeneous group. Different consumers will require different services and thus different smart meters. "One size fits all" will not work. These reflections plead for a modular architecture of the smart meters. This is best seen when the different services are analysed from the consumers' point of view.

3.2.1 Focussing on the household's viewpoint

A particular attention should be given to ***local feedback on consumption (real-time and historical)*** and ***personalised consumption advice***. Today's studies show "an average" of 2% to 4% energy savings in the best of cases (see section 2.3). We must be very careful about this for three reasons:

(1) Energy savings are unequally distributed between consumers and are very dependent of motivation and skills of the consumers to achieve such savings.
(2) Feedback systems and personalised advice are bound to evolve very rapidly. To our knowledge, no large scale survey has been done with advanced techniques such as comprehensive feedback on disaggregated consumption and on corresponding energy saving practices (see 3.1.4). Smart meters must therefore remain future-proof and allow for the seamless integration of displays yet to be developed and of communicating means with external advice providers, such as ESCos.
(3) Demand-response, although not clearly defined today, will most probably play an important role on the consumption patterns, either as a way to reduce energy consumption or at least to provide load shifting.

The benefits for consumers are essentially related to the ***energy savings*** they can achieve. These estimations were typically in the range 5%-15% five years ago but are now estimated between 0% and 4%. A better comprehension of energy saving practices and the impact of comprehensive feedback and advice could lead to re-evaluating these figures upwards in the future.

Rather than speculating on these figures, we recommend that all the smart meters that will be deployed from now on be open for interconnecting to future advanced services such as ***comprehensive feedback and personalised advice***. This implies the existence of an interface on the smart meter providing full detailed consumption data under the sole control of the consumer himself. Households could then choose the service that they would need according to the evolution of the market. These services could be implemented as new devices or as remote services provided by ESCos. In the meantime, existing systems with limited feedback capabilities, such as most of today's IHDs, should remain optional, either free of charge or charged proportionally to the energy consumption.

Finally, for ***demand-response*** the same logic should apply. To avoid a lock-in or stranded assets if smart meters ought to be replaced before their end-of-life, we also recommend, at no extra cost for the consumers, that a slot for adding functionalities after the deployment of the smart meter is already foreseen. Smart meters plug-ins could then create a new competitive market.

The technical feasibility of such extension is described in the following sections.

3.2.2 Deploying modular solutions while there is still time

The following diagram, inspired by fig 3 of M/441[28], shows that electricity metering systems can also be used for other utilities (water, gas, heat, etc.) but, most importantly, shows what are the different uses of the data provided by the metering system: technical and commercial use cases and the role of local display and home automation.

[28] Standardization mandate to CEN, CENELEC and ETSI in the field of measuring instruments for the development of an open architecture for utility meters involving communication protocols enabling interoperability, Final Report, Version 0.7 – 2009-12-10.

The main interest of such a drawing is that the communication part (ICT) clearly appears as a necessary block for providing information to these different actors. It confirms should this be still necessary, that the ICT infrastructure serves all of them and is therefore the core of the split incentive issue.

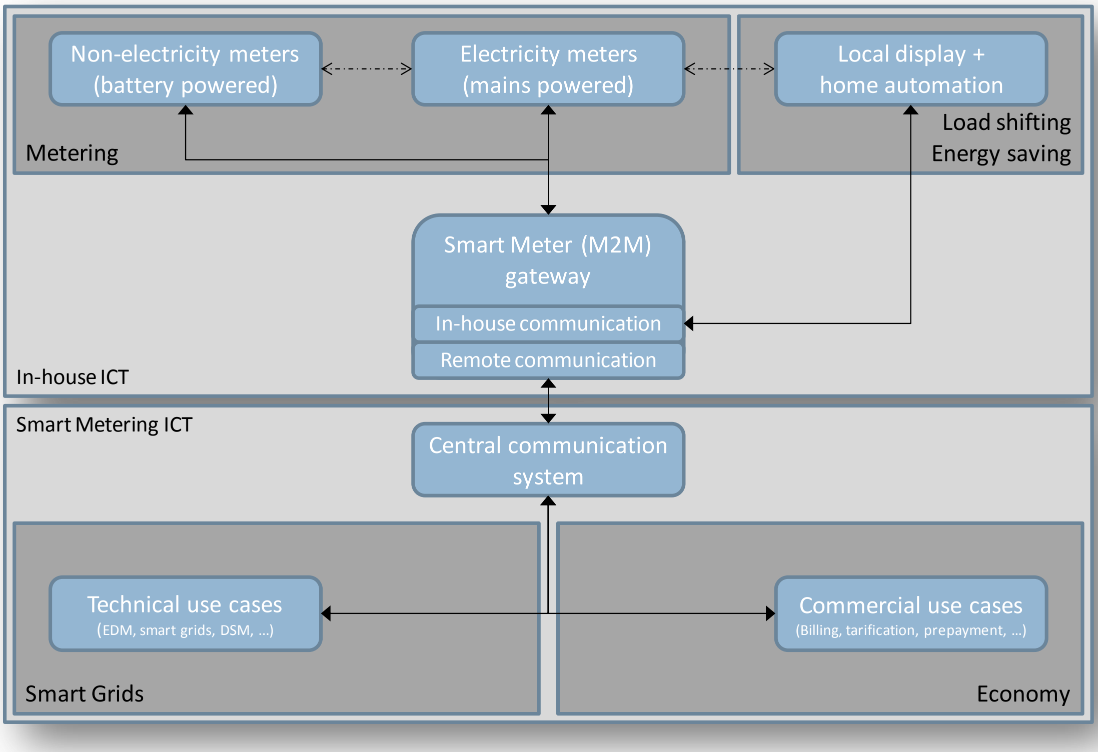


Figure 3.1: Preventing techno-economical lock-ins

Most importantly, beyond the "who pays for what" issue, we can also see that ICT constitutes the most critical part for the creation of a new techno-economical lock-in, which should be, following us, one of the main points of attention.

Without going into technical details, starting from the electricity meter, we can identify the following ICT components: the Smart Meter Gateway (responsible for securely transmitting data to other components), the in-house communication module (for the communication with IHDs and home automation systems) and the remote communication modules (for the communication with the central communication system of the MDM).

We argue that these components should be modular and developed within an open architecture with a clearly defined interface. The main advantages are:

- avoiding techno-economical lock-ins and stranded assets related to different maturity and obsolescence rates;
- opening and boosting the energy services markets;
- enabling progressive deployment.

These points are clarified below.

The Electricity meter is the base of the system as it is the component that is responsible for computing the consumed energy and holding the registers. The Metering Instrument Directive

(2004/22/CE) clearly defines what such meter is and what may be included in it. For instance, such meter must always be functional, even if the remote communication is out of order.

The Smart Meter Gateway is a typical ICT equipment, having to communicate at least with the electricity meter itself, the in-house devices (often considered as a home area network – HAN), and externally with the Central Communication System (or Meter Data Management Systems – MDM). This latter link, the remote communication, is particularly important as the information flowing though it will control the enablement/disablement, the maximum power available to the household, the data for billing and maybe the detailed consumption data. This link must therefore be well secured.

3.2.3 Different maturity and obsolescence rates

A hardly discussed topic is the fact that today's typical integrated smart meters include technologies that are in totally different stages of maturity.

The electricity meter component is based on mature technologies. Analogue meters had a lifetime of over 30 years and new electronic meters are expected to work well beyond 10 years.

The in-house communication with IHDs, energy boxes or other home automation is not well standardised yet. In the coming years, energy-management devices and services will appear on the market. In parallel, home communication protocols are also evolving rapidly: Ethernet, Wi-Fi, Zigbee, Z-wave, etc. are competing in this area. Today, no one has a clear picture of how the HAN market will look like in 5 years from now.

The remote communication situation seems less complex because, in most EU countries, the choice of this communication channel is under the sole control of the DSOs who generally favour PLC technologies because this allows them to retain full control on the transmitted data. However, telecom operators, with GSM-based and xDSL-based solutions can provide cheaper communication paths with higher throughputs than PLC. It should also be stressed that none of the available technologies have 100% coverage[29], so mixed solutions are always necessary. It is also difficult to predict how the market will be within a few years from now.

Finally, the Smart Meter Gateway, responsible for managing the above components and dispatching data between them, is also in charge of the *security* of the communication with the central communication system. Because of the criticality of the data flowing through this channel, a high level of security is necessary. Probably conscious of this fact, the German Federal Office for Information Security issued criteria on the protection profile for the gateway of a smart metering system in July 2011[30], defining the minimum security requirements of future smart meter gateway devices to be used in household installations. This level of security is comparable to that of the banking environment, and that raises the issue of key management and regular security upgrading.

For the different reasons developed above, it seems unreasonably optimistic to expect that a fully integrated smart meter having all these functions in one device will have a life expectancy of 10 to 15 years, which are yet the figures used in various cost-benefit analysis. Should it be effectively so, this would at the very least hinder the IHD, home automation and ESCo markets as they would be limited to what is defined today for the in-house communication channel.

Therefore, we strongly believe that:

---

[29] See for example: Studie communicatiemiddelen voor slimme meters, VREG 2006/0192, May 2007

[30] **http://www.frost.com/prod/servlet/market-insight-top.pag?Src=RSS&docid=241350409**

- the in-house communication channel should be implemented as a pluggable module (such as a USB port) and that this port should be under the sole control of the household so that the consumer will be fully entitled to use it according to his needs: using various versions of IHDs yet to appear on the market, forwarding information to a selected ESCo, using data locally, etc.
- In the same way, the remote communication channel should also be provided as a pluggable module. Smart meters with external communication slots already exist on the market (Siemens, Landys+Gyr, etc.). It enables a SM to work with different technologies: PLC (Primes, SFK, OFDM, etc.), GPRS, broadband xDSL, etc. This module would remain under the control of the metering management system (DSO in most countries) and would allow migration from one technology to another according to the evolution and the communication market.
- The security must also be modular. Either it should be integrated directly in the remote communication module or in a smart card (such as a SIM card used for mobile communication). Integrating security into the smart meter gateway directly is also possible, but in such a case, security should be evaluated taking into account a lifetime of 15 years. Such solutions exist and are used in banking environments.
- Finally, the smart meter itself should be installed on a standardised "smart meter plug" as smart meters are bound to be changed every 10 years or less if sufficient modularity is not implemented. Standards for such smart meter connectors already exist in the US and in Germany.

However, one must not underestimate some additional costs related to modularity (connectors, software development, etc.). Nonetheless, we are quite confident that a global cost-benefit analysis taking all the technical and economical aspects into account would be positive due to reduced stranded assets and new market opportunities.

3.2.4 Opening the energy service markets

One of the (missed) goals of the Energy Service Directive (2006/32/CE) was to promote energy services by developing Energy Service Companies (ESCo). Though they have developed in some sectors, they have not penetrated the household sector yet.

Unfortunately, today's smart meters do not provide an easy mean for such services to be developed. Indeed, most in-house communication interfaces are based on the IEC 62056-21 standard which is a local serial interface that can be accessed either optically or wired.

Further energy services, such as full consumption disaggregation in order to provide personalised advice requires other communication means. In the same logic, further development of the smart grid and home automation may also require interconnection with other protocols[31].

It would be a missed opportunity to limit the in-house communication of the smart meters, especially because proposals for universal metering interfaces already exist[32]. Not doing so will most likely create a technical lock-in and limit the market of energy-related services or products.

Furthermore a modular approach also enables progressively replacing conventional meters by smart ones (for example during other maintenance actions), even if the remote communication protocols are not decided yet.

[31] For example: KNX, LonTalk, Modbus, ZigBee, etc.

[32] For example the Universal Metering Interface (http://www.cambridgeconsultants.com/downloads/literature/UMI_overview.pdf)

3.2.5 Summary

The modular architecture proposed above includes a pluggable in-house communication unit, a pluggable remote communication device and a low-cost means of upgrading security (SIM cards or integration in the remote communication unit). Moreover, the entire smart meter is also connected to the household's main supply through a standardised plug allowing for an easy replacement.

The proposed solution reduces replacement costs in the future, allows opening of the energy service market and facilitates progressive deployment.

3.3 Open data society: from Internet to Interwatt

The smart grid hypothesis is based on the possibility to superpose a communicational network to the electricity grid. Smart grids are where electricity and the Internet meet. We believe that the interest of consumers is to go **towards open source smart grids**, that we call **Interwatt**. Taking seriously the idea of 'active consumers' we are led to see the grid and the uses in their heterogeneity. Consumers have different agendas and approaches that contrast with the centralised model of production of electricity and of collecting data. The cooperation between active users is needed to achieve the 2020 and 2050 targets (see 1.2). That implies however that consumers can develop their own interests and meanings in the smart meters. Considering the smart grids as an 'open source' system means also that the roles of the different actors are not yet completely frozen. If consumers have to become active, that implies enabling them to appropriate new technologies and invent new uses.

Interwatt would give the possibility to 'energy techies' to blossom and develop solutions that fit to their needs. It would allow users to develop original design and scripts, and collaborative work could emerge. It would foster creativity in multiplying bottom-up initiatives. Flexibility is also required to promote the production and sharing of green electricity at a local scale. Electricity could be shared as information is shared on the Internet, provided that the property of the means of electricity production is fairly distributed. In any case, to avoid lock-ins and develop ingenuity from the users, those must have a free access to their consumption data. Interwatt would encourage sharing small DIY tricks or clever devices.

A reconfiguration of our socio-technical landscape is needed in order to moralize the behaviour of users (Jelsma 2006). This moralisation of uses may be smooth if smart meters are voluntary domesticated and appropriated. The deployment of SM should allow users to participate to the smart grid development, and to the necessary change of consumption patterns. This is a general principle, for we know that only a few people will be real developers. But allowing 'techies' to appropriate the new technology is a way to speed up the transition towards a low carbon society very much in the same way open source and the Internet has increased low cost high performance software development.

We are all consumers, but not all consumers will be empowered in the same way. We presume that this report is read by a pretty narrow class of European consumers: well educated, with incomes that enable them to live a comfortable life. And we include ourselves in this class. But we cannot presume how our dear readers consume and save energy!

Recommendations

We recommend a progressive deployment, according to the demand rhythm, of modular smart meters. Everything pleads for a solution that leaves the possible uses of SMs as open as possible, as well as their potential technical and usage evolution. We have gathered different arguments in favour of real options and choices for the consumers, grasped in their diversity:

- To avoid technological lock-ins, consumers and meters, together with uses and meanings, have to evolve in cooperation.
- Feedback devices work only with consumers who have opted for the use of a smart meter. The diversified needs of consumers cannot be met by a unique device.
- The modularity of the meters should enable a progressive development of the functions and the uses. It will allow consumers to actively participate in new uses. Consumer’s interests and needs will be more satisfied if users can be involved in the design of the instruments.
- Monopolies should not be created nor the existing ones reinforced. DSO is a natural monopoly. If it can get all the data for free it will extend its monopoly to data management, whose value can only rise. New possibilities for ESCos and experimentations should be fostered instead.
- The recommendations are technically feasible.

The present chapter recapitulates the recommendations that are scattered in the previous parts. Let’s remind that we have not directly considered the issues of privacy and security.

4.1 Acceptable deployment schemes for consumers

Smart meters should be deployed in a manner that reduces deployments costs, stranded assets and stays in line with household expectations. Only consumers that can effectively make significant energy and money savings should pay for a system that will mainly benefit other actors. Through the introduction of smart meters, energy savings might be achieved only for a limited range of consumers. We therefore recommend 3 different scenarios that:

- avoids the privacy issue and reduces legal risk;
- limits the deployment costs;
- recruits only consumers who can effectively make savings;
- enables the creation of a full ESCo market;
- is open to any consumer;
- can evolve at a different pace or rhythm than the one achieved by the DSO (10-15 year replacement period);
- organises the competition on services, not only on energy.

<u>Baseline scenario:</u>

Metering responsible entities (DSO in most countries) are entitled to replace (e.g. during maintenance or other interventions), <u>without specific consent of the consumers</u>, existing analogue meters by electronic meters, provided that:

a. Smart meters are installed on a standardised socket that will allow an easy future replacement or upgrade — as electronic technology evolves fast, it is important to leave the future open at a low cost. Moreover, this reduces the replacement cost and makes it possible to change the legal framework where metering is related to the DSO (e.g. in Germany).

b. Smart meters will not be equipped with a remote communication module that allows the remote reading of registers.
c. This replacement is free of charge for the consumer.

With the consent of the consumer, the smart meters may be installed in households provided the following additional features are included:

a. The smart meter is equipped with a remote communication module that allows on demand reading of registers with a maximum rate of once a month or on-demand reading for move-in/move-out or for supplier change.
b. The smart meter is equipped with a free accessible communication port for in-house communication. Aside from the monthly reading, consumers have the advantage of getting access to their own consumption data. A USB connector for storing consumption data can be added so that users can do off-line consumption analysis, for example on a PC. This could be the first step towards energy consumption awareness.
c. Remote enablement/disablement and power limitation may be included, but disablement and power limitation may only be used at the end of a contract with the consumer or with his consent.
d. The smart meter is free of charge for the consumer.

This baseline scenario might be accepted by most consumers as it remains free of charge and gives them access to their own consumption data. On the other hand, they must explicitly accept remote reading of their registers once a month. Such baseline scenario is similar to the current roll-out in the Netherlands. It leaves to the market the role of convincing households that there is a real added value for them, by offering tangible services at a price they are willing to pay. Moreover, this scenario also allows the progressive and low-cost deployment of smart meter technology, without consent of the consumer during maintenance or other interventions at the customer's premises. It also permits the way for the two next options.

OPTION 1: Smart Meter with Feedback

With the consent of consumers, this option foresees the following additional features:

- A real-time feedback system with historical consumption.
- A fee can be requested to the consumers for this service. This fee may be included in the energy supply contract, but the consumer must be able to withdraw.

The feedback system would typically be an in-house display, the data coming from the in-house communication port of the smart meter. However, other feedback systems, such as websites or software running on local computers or smartphones, can also be proposed.

As these feedback systems do not need to be dependent on the DSO infrastructure (data coming from the in-house communication port), many innovative systems may emerge and adapt at market pace, to the rhythm of changing needs of every consumer (e.g. new equipment, submetering capabilities, electrical vehicles).

OPTION 2: Smart Meter for energy services

The consumer may request additional energy services based on the smart meter data. Such services should be contracted separately with an ESCo or any other entity proposing products or services using the in-house communication port. Energy suppliers should also be entitled to provide such services.

The openness of such a solution allows a multitude of advanced services to be offered: simple or advanced feedback, demand-response services, home automation, home security, aggregation services, remote diagnostics, etc.

Reciprocally, the increased offering of new services to households will also promote the consumer willingness to be equipped with such smart meters.

Besides such commercial services, consumers will have their consumption data in their hands and part of them will develop DIY solution. Similarly, citizen groups, energy challenges, energy games, etc. can also become active actors in such a construction.

Taking households step by step through the different options, reducing their fear in data privacy issues and having a multitude of players developing new and innovative energy services is the best way to increase consumer's willingness to participate in the smart metering adventure.

4.2 Profiling consumers

Smart meters can lead to energy consumption reduction, if it is associated to feedback (real time or historical) and energy advices. In these best cases, recent studies in some European countries (UK, Ireland, Germany) have shown that 2-4% of energy reduction can be expected[33], with the assumption that:

- households have opted in;
- energy savings are measured within the first year after the introduction of the SM. Drawback effects are observed afterwards;
- feedback is done on the total aggregated electricity consumption.

It is crucial to associate a range of customised instruments in order to improve the feedback and prevent the drawback effect[34]. In-home displays need to be explained and information needs to be clear and vivid. Interfaces and advices can probably be improved yet. As a limitation comes from the fact that feedback is about aggregated data, it is important to develop disaggregate feedback (by appliance). The costs of these associated instruments should be assessed as well when performing a CBA.

However, the conditions of appropriation of smart meters by households differ greatly. Through our theoretical analysis of the studies, we conclude that two types of households are worth being targeted for an optional rollout:

- Households whose consumption is largely above the per capita average and who are motivated to save energy.
- Households who have a per capita average consumption and are both motivated and capable to save energy.

[33] This amounts to around 15 to 30 saved euros per year for an average European household.

[34] This also can be done by auditors coming to analyse the bills and checking throughout the households what can be done in order to reduce consumption.

Consumers in fuel poverty could also benefit from customised feedback[35]. However more research is needed to assess this potential for we lack of explanation about how households achieve their energy savings.

4.3 Carrying out cost-benefit analyses

The Directive concerning the internal market in electricity (2009/72/CE) requires that each Member State should carry out a cost-benefit assessment (CBA) before September 3rd, 2012. Where the rollout of smart meters is assessed positively, at least 80% of consumers shall be equipped with intelligent metering systems by 2020. We recommend that CBAs consider different scenarios AND the diversity of consumption levels. By scenarios we mean to assess different kinds of "smart meters", and that includes the functionalities and the corresponding technical system. The baseline, option 1 and option 2 are for instance scenarios that would lead to different CBA results.

Each scenario should be evaluated through a CBA for different electricity consumption levels (e.g. in function of energy consumption deciles). This is allowed by the 2009/72 Directive. And different costs should be included (e.g. electricity consumption of the new ICT network).

The CBA of a given scenario can result in 2 different cases:

- The analysis is positive for all the population segments. Therefore smart meters can be deployed according to this scenario. However, split incentives and the amount to be charged to the consumers (currently estimated between 30 and 50 € per year) would need to be defined independently for each segment so that none of them would have to pay for the others.
- The result is positive only for some restricted population segments. (We suppose that it is always possible to identify population segments that yield to a positive CBA.) The opt-in from consumers is then required and should be controlled by national energy regulators so that consumers are not forced to opt-in by default.

4.4 Meter and grid management

DSO and suppliers can have an interest to develop functionalities that might be detrimental to consumers.

Remote enablement/disablement and maximum power setting of the meters are clear advantages of smart meter infrastructures. Indeed, consumers get a faster service when moving in and DSO can react faster and spare workforce, as physical displacement is not required anymore for such operations. However, the usage of these features should be controlled by a regulator, as this type of service can provide suppliers or DSO with excessive means to put pressure on customers (e.g. in case of unpaid invoices, disagreements, errors).

The type of information required for grid management depends on the topology of the network, the type of loads, the presence of distributed generation (e.g. photovoltaic) and many other parameters. However, data can roughly be categorised in two groups: real-time information for the direct management of the network (smart grid features) and monitoring information, less time-critical, used for analysing energy flows or incidents and to manage the network on a longer term (capacity

[35] Note that the Queen Elizabeth seems to be a good target for she seems to meet both conditions of extravagance and fuel poverty. See “Soaring prices push Queen close to ‘fuel poverty’”, Financial Times, 21 October 2011.

planning). Detailed quarter-hourly measured load curves can be useful for these purposes. DSOs are therefore interested in deploying an advanced metering infrastructure having such capabilities. It should however be pointed out that, for this sole purpose, it is not necessary to have a measuring point in each household. Making measurements for groups of households, on the same distribution cable or in large buildings is in most cases enough. We therefore recommend that this feature be independent of individual meters except where consumers have agreed to install them. But in any case, consumers should be able to retrieve their data and sell them or give them to a third party in exchange for their services. This option should be regulated through a clear procedure and adequate information campaigns in order to prevent implicit opt-in.

4.5 Tariff schemes

Some studies show that time of use tariffs (ToUT) can lead up to a 10% shift in the energy consumption from peak hours to other hours — but that the net energy savings are much lower. ToUT is merely an extension of the day-night logic and simply introduces a predefined set of time periods with different prices for each period. Current experiments have used simple ToUT, and we recommend that future ToUT remain simple because:

- to be efficient, ToUT must be appropriated by households;
- households won't be able to understand complex and changing tariffs.

Therefore the diversity of tariffs should be regulated on the basis of what experiments have done (maximum 3 fixed tariffs).

For the same reason of simplicity, we advice against dynamic pricing that reflects the actual price of the wholesale market price.

We recommend however to develop more research on Critical Peak Pricing (CPP), for we believe that this tool is much more educative. CPP is a way to warn households that energy prices will be exceptionally high (a few times per year) during a certain period of time. It is generally announced through classic media. This kind of measure is interesting because it shows that at some points we touch the limit of what the energy system can provide.

In the same perspective, the energy issue is not only a question of total energy consumption (in kWh), but also of high power demand at some time. It could then be interesting to develop indicators of minimum and maximum consumption (in kW): that would pave the way to other tariffs that could reward households who remain below a given level of power (kW) at any time. But before, energy literacy will have to be improved.

Besides the pricing itself, the payment scheme is also important for the consumer. Like in the telecom market, electricity may be paid after receiving the bill (post payment) or in advance (prepayment). Presently, changing from one payment mode to the other generally involves the costly physical change of the meter itself. Smart meters can provide the remote switching between prepayment and post payment at almost no extra cost. As low income households could be gently forced to adopt prepayment meters, we recommend that prepayment methods and pricing be regulated.

4.6 Reframing the energy issue

In order to increase the number of 'receptive consumers' towards smart meters, the general frame of energy has to change. We need more experiments in order to understand which transformations are feasible and desirable, including the emergence of new social norms and values. These experiments would integrate smart meters in a broader framework of meanings, beyond plain financial and ecological motivations. We recommend developing new energy policies and measures that go beyond the information paradigm. For instance:

- Progressive tariffs.
- Energy (savings) could be translated into a **complementary currency**. That would make energy much more visible, and would allow linking a range of actions to the energy consumption.
- Developing experiments at the community level (smart cities or eco-neighbourhoods).
- Personal carbon trading schemes.
- Make energy saving a public issue, in mobilising civil society for instance. Education and work are places where energy issues could be tackled.

The experimentations should be carefully conducted and studied. They require free access to data by all organisations and researchers, and overall by users themselves.

4.7 Interwatt: towards an open data society

The interest of consumers is clearly to go towards an 'open source' management of the smart meters and grids. That would allow the most technically skilled to develop and share original ideas. To release this potential source of creativity, we recommend that:

- Consumers have unrestricted access to their data, past and present. The retrieval of data must then be free, and past data always available even when switching (i.e. changing of supplier).
- Consumers have an unlimited right to use and exchange their raw consumption data, namely independently of any secondary treatment or transformation by a software.
- Consumers can give their data under license to a third party (e.g. an ESCo).

These measures will enable open source developments (e.g. by users or ESCo's).

4.8 Smart meter modularity

To achieve the aforementioned advantages, it is necessary to avoid technological lock-ins and open the energy saving issue to concerned stakeholders, not only DSO and suppliers. We have added this set of recommendations to show that the smart meter modularity is technically feasible.

- **Socket for the meter itself.** We recommend installing the smart meters on a standardised socket, similar to what is done in Germany (eHZ 2.1 standard).**Communication channel to the DSO.** Either the meters should be mounted on a standardised connector to ease replacement OR the communication module should be a pluggable module. Most meter manufacturers already propose this solution. It should become obligatory. The standardisation of the connector, the physical characteristics and the protocols should be encouraged to increase competitiveness and cost reduction.
- **In-house communication channel.** Either the meters should be mounted on a standardized connector to ease replacement OR the meter should provide the consumption data on a local port. This local port should allow a pluggable module for local processing or communication with in-house devices such as in-house displays or gateways to ESCos. The standardisation of the connector, physical characteristics and the protocols should be encouraged to increase competitiveness and cost reduction.

References

Abrahamse, W., Steg, L., Vlek, C., Rothengatter, T. (2005) A review of intervention studies aimed at household energy conservation, *Journal of Environmental Psychology* 25, 273–291.

Akrich M. (1995), "User Representations: Practices, Methods and Sociology", in Rip A., Misa Tj., Schot J. (ed.), *Managing Technology in Society. The Approach of Constructive Technology Assessment*, London, Pinter, pp. 167-184.

Anker-Nilssen P. (2003), "Household energy use and the environment – a conflicting issue", Applied Energy, 76, pp. 189-196.

Aune, M. (2007), "Energy comes home", *Energy Policy* 35, pp. 5457–5465

Bang M., Tortensson C., Katzeff C. (2006), "The powerhouse: A persuasive computer game designed to raise awareness of domestic energy consumption", Lecture Notes in Computer Science, Vol. 3962, pp. 123--132.

Bartiaux F. (2007), "Does environmental information overcomes practice compartmentalization and change consumer behaviours?", *Journal of Cleaner Production*, vol. 16, pp. 1170-1180.

Bartiaux F., Vekemans G., Gram-Hanssen K., Maes D., Cantaert M., Spies B., Desmedt J. (2006), *Socio-technical factors influencing Residential Energy Consumption*, Research conducted for the Belgian Science Policy.

Bird J. & Rogers Y. (2010), "The Pulse of Tidy Street: Measuring and Publicly Displaying Domestic Electricity Consumption", Workshop on Energy Awareness and Conservation through Pervasive Applications.

Bladh M. (2010), "Energy efficient lighting meets real home life", Energy Efficiency, pp. 1-11. Published on line.

Brohmann B., Heinzle S., Rennings K., Sleich J., Wüstenhagen R. (2010), "What's driving sustainable energy consumption? A survey of the empirical literature", Centre for European Economic Research, Discussion Paper No. 09-013.

Carlsson-Kanyama A., Lindén A-L. (2007), "Energy efficiency in residences - Challenges for women and men in the North", *Energy Policy* 35 (4), 2613-2172.

CER (2011), Smart Metering Project Phase 1 Updates, Irish Commission for the Energy Regulation, retrieved from: http://www.cer.ie/en/information-centre-reports-and-publications.aspx.

COM(2007) 723 final - Communication from the Commission to the Council, the European parliament, the European economic and social Committee and the Committee of the regions, A European Strategic Energy Technology Plan (Set-Plan), 'Towards a low carbon future'

COM(2009) 039 final - Communication from the Commission to the European Parliament, the Council, the European economic and social committee and the Committee of the regions, Towards a comprehensive climate change agreement in Copenhagen

COM(2009) 400 final - Communication from the Commission to the European Parliament, the council, the European economic and social committee and the Committee of the regions, Mainstreaming sustainable development into EU policies: 2009 Review of the European Union Strategy for Sustainable Development

COM(2010) 677 final - Communication from the Commission to the European Parliament, the Council, the European economic and social committee and the Committee of the regions, Energy infrastructure priorities for 2020 and beyond - A Blueprint for an integrated European energy network

COM(2011) 021 final - Communication from the Commission to the European Parliament, the Council, the European economic and social committee and the Committee of the regions, A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy

COM(2011) 109 final2 - Communication from the Commission to the European Parliament, the Council, the European economic and social committee and the Committee of the regions, Energy Efficiency Plan 2011

COM(2011) 112 final - Communication from the Commission to the European Parliament, the Council, the European economic and social committee and the Committee of the regions, A Roadmap for moving to a competitive low carbon economy in 2050

COM(2011) 202 final - Communication from the Commission to the European Parliament, the Council, the European economic and social committee and the Committee of the regions, Smart Grids: from innovation to deployment

COM(2011) 370 final - Proposal for a Directive of the European Parliament and of the Council on energy efficiency and repealing Directives 2004/8/EC and 2006/32/EC

Commission staff working paper interpretative note on Directive 2009/72/EC concerning common rules for the internal market in electricity and Directive 2009/73/EC concerning common rules for the internal market in natural gas, retail markets, January 22, 2010

Darby, S. (2006), "The effectiveness of feedback on energy consumption. A review for DEFRA of the literature on metering, billing and direct displays, DEFRA.

Darby, S. (2007), "Enough is as good as a feast – sufficiency as policy", ECEEE 2007 Summer Study.

De Young, R. (2000). Expanding and evaluating motives for environmentally responsible behaviour. Journal of Social Issues. 56(3): 509-26.

Directive 2005/32/EC of the European Parliament and of the Council of 6 July 2005 establishing a framework for the setting of ecodesign requirements for energy-using products and amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC of the European Parliament and of the Council

Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC

Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC

Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings

EDRP (2011), Energy Demand Response Project : A final analysis, AECOM, Report commissioned by Ofgem on behalf of DECC, retrived from :
http://www.ofgem.gov.uk/Sustainability/EDRP/Pages/EDRP.aspx

Ehrhardt-Martinez K., Donnelly K. & Laitner J. (2010), Advanced Metering Initiatives and Residential Feedback Programs: A Meta-Review for Household Electricity-Saving Opportunities, American Council for an Energy Efficient Economy.

ERGEG (2011), Final Guidelines of Good Practice on Regulatory Aspects of Smart Metering for Electricity and Gas, Ref: E10-RMF-29-05.

ESMIG (2011), Empower Demand. The potential of smart meter enabled programs to increase energy and systems efficiency: a mass pilot comparison. Authors : J. Stromback, C. Dromacque & M. H. Yassin (VaasaETT).

Fawcett T. & Parag Y. (2010), "An introduction to personal carbon trading", Climate Policy 10 329–338.

Fischer C. (2008) Feedback on household electricity consumption: a tool for saving energy?, Energy Efficiency 1, 79–104.

Foxon T. (2011), A coevolutionary framework for analysing a transition to a sustainable low carbon economy, Ecological Economics 70 (2011) 2258–2267.

Frontier Economic (2011), Economic Potential of Smart Electricity Meters in Germany, Analysis Commissioned by Yello Strom. Retrieved from :
http://www.frontier-economics.com/_library/pdfs/frontier-potential%20smart%20metering%20-%20kurzgutachten-en.pdf

Gatersleben B., Steg L., Vclek C. (2002), "Measurement and Determinants of Environmentally Significant Consumer Behavior", Environment and Behavior, 2002 34: 335-362.

Gram-Hanssen, K. (2010), Residential heat comfort practices: Understanding users. Building Research and Information, 38(2), 175-186.

Gram-Hanssen, K. (2011) Understanding change and continuity in residential energy consumption, Journal of Consumer Culture 11, 61-78.

Greening, L.A., Greene, D.L., Difiglio, C, (2000). "Energy efficiency and consumption – the rebound effect: A survey", Energy Policy, 28, pp. 389-401.

Haas, R. (1997), Energy efficiency indicators in the residential sector. What do we know and what has to be ensured?, Energy Policy 25, 789-802.

Hargreaves, T., Nye M. & Burgess J. (2010), Making energy visible: A qualitative field study of how householders interact with feedback from smart energy monitors, Energy Policy 38, 6111–6119.

Henk van Elburg (2008): Report on Effective Customer Feedback Mechanisms, Deliverable 6, Work package 2, Task 2 and 3 of ESMA-Project, supported by IEE, July 2008.

IPCC (2007), Fourth Assessment Report (AR4): http://www.ipcc.ch/

Jackson, T. (2005), Motivating Sustainable Consumption. A review of evidence on consumer behaviour and behavioural change, A report to the Sustainable Development Research Network: http://www.comminit.com/en/node/219688

Jackson, T., (2009), *Prosperity without Growth: Economics for a Finite Planet*. Earthscan,London.

Jelsma, J. (2003), "Innovating for sustainability: Involving users, politics and technology", Innovation 16, pp. 103-116.

Jelsma, J. (2006). Designing 'moralized' products: theory and practice. In Verbeek, P-P. & Slob, A. (Eds), *User behavior and technology development: shaping sustainable relations between consumers and technologies*, Springer.

Jensen J. O. (2008) Measuring consumption in households: Interpretations and strategies, Ecological Economics 68, 353–361.

Kahneman, D. & Tversky, A. (1979). Prospect Theory: An Analysis of Decision under Risk, *Econometrica* 47, 263-291.

Kalma J.D., Crossley D.J., 1982, "Inequities in domestic energy use: some determinants", *Energy Policy* 10 (3), pp. 233-243.

KEMA (2008), Resultaten van een kosten-batenanalyse naar de invoering van 'slimme meters' in Vlaanderen, finaal rapport, KEMA Nederland B.V.

KEMA (2009), Cost-benefit Analysis of the introduction of smart meters in the Brussel Capital Region, Version 0.3 (final), KEMA International BV, 6 April 2009, page 34

Klopfert F. & Wallenborn G. (2011), "Les 'compteurs intelligents' sont-ils conçus pour économiser de l'énergie ?", *Terminal* 106- 107, 87-100.

Langenheld A. (2010), Advanced metering and consumer feedback to deliver energy savings – Potentials, Member States experience and recommendations, Report prepared by the Joint Research Centre of the European Commission.

Latour B. (2008), "A Cautious Prometheus? A Few Steps Toward a Philosophy of Design (with Special Attention to Peter Sloterdijk)", Keynote lecture for the Networks of Design* meeting of the Design History Society Falmouth, Cornwall, 3rd September 2008.

Lehtonen T-K (2003), The domestication of new technologies as a set of trials, *Journal of consumer culture* 3, pp. 363-385

Leighty, W. and A. Meier (2011), "Accelerated electricity conservation in Juneau, Alaska: A study of household activities that reduced demand 25%", *Energy Policy* 39 (5), 2299-2309.

Liikkanen L. (2009), Extreme-user approach and the design of energy feedback systems. In Proc. of EEDAL 2009 - 5th International Conference on Energy Efficiency in Domestic Appliances and Lighting.

Lockton D., Harrisona D. & Stantona N. (2008), Making the user more efficient: Design for sustainable behaviour, *International Journal of Sustainable Engineering* 1, 3-8.

Lutzenhiser, L. and Lutzenhiser S. (2006), "Looking at Lifestyle: The Impacts of American Ways of Life on Energy/Resource Demands and Pollution Patterns", 2006 ACEEE Summer Study on Energy Efficiency in Buildings.

Manzini, E. (2009). New design knowledge, *Design Studies* 30, 4-12.

Martiskainen, M. & Ellis, J. (2011), The role of information and communication technologies (ICTs) in household energy consumption - prospects for the UK, Energy Efficiency (to be published).

Marvin S., Chappells H. & Guy S. (1999), Pathways of smart metering development: shaping environmental innovation, Computers, Environment and Urban Systems 23,109-126.

McMakin A.H., Malone E.L., Lundgren R.E., 2002, “Motivating residents to conserve energy without financial incentives”, Environment and Behaviour, 34 (6), 848-863.

Morley, J. & Hazas M. (2011), “The significance of difference: Understanding variation in household energy consumption”, ECEEE Proceedings.

Nye, D. E. (1998), Consuming Power: A Social History of American Energies, Cambridge, Mass., MIT Press.

O’Neill B.C. & Chen B.S., 2002, “Demographic Determinants of Household Energy Use in the United States”, *Population and Development Review* 28, pp. 53–88.

Pantzar, M., (1997), “Domestication of Everyday Life Technology: Dynamic Views on the Social Histories of Artifacts”, *Design Issues* 13, pp. 52-65.

Pasquier S. (2011), Saving electricity in a hurry, IEA information paper.

Pierce J., Schiano D. & Paulos E. (2010), Home, Habits, and Energy: Examining Domestic Interactions and Energy Consumption, Proceedings of *CHI 2010 Conference,* April 10–15, Atlanta.

Pred A., (1981), “Social reproduction and the time-geography of everyday life”, *Geografiska Annaler* 63, 5–22 B.

Prignot, N. & Wallenborn G. (2009), “Standardisation of practices and representations of users in the ecodesign Directive”, Proceedings of ECEEE Conference, 1-6 June 2009, La Colle-sur-Loup, France.

Reckwitz, A. (2002), “Towards a Theory of Social Practices: A Development in Culturalist Theorizing,” *European Journal of Social Theory* 5, pp. 243–63.

Renner S. & Martins F. (2010), Individual metering and informative billing, Technical Summary Report TSR03, www.esd-ca.org

Renner S., Albu M., van Elburg H., Heinemann C., Łazicki A., Penttinen L., Puente F. & Sæle H. (2011), European Smart Metering Landscape Report - SmartRegions Deliverable 2.1.. http://www.smartregions.net/

Røpke, I. (2001), “New technology in everyday life - social processes and environmental impact”, *Ecological Economics* 38, pp. 403-422.

Røpke, Inge (2009), “Theories of practice -- New inspiration for ecological economic studies on consumption.” *Ecological Economics* 68:2490-2497.

Rüdiger, M. (ed.) (2008), *The Culture of Energy*, Cambridge Scholars Publishing.

Schatzki, T. (1996), *Social Practices: A Wittgensteinian Approach to Human Activity and the Social*, Cambridge, Cambridge University Press.

Schatzki, Theodore R., Karin Knorr Cetina and Eike von Savigny (eds) (2001), *The Practice Turn in Contemporary Theory*. London & New York: Routledge.

Schleich J., Klobasa M., Brunner M., Gölz S., Götz K. & Sunderer G. (2011), Smart metering in Germany and Austria – results of providing feedback information in a field trial, Working Paper Sustainability and Innovation No. S 6/2011, Fraunhofer ISI, Karlsruhe. Retrieved at:
http://www.isi.fraunhofer.de/isi-de/service/presseinfos/2011/pri11-13.php

SEC(2009) 1295 final - Commission staff working document - Accompanying document to the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on Investing in the Development of Low Carbon Technologies (SET-Plan) - A technology roadmap

Shove, E. (2003), *Comfort, cleanliness and convenience: the social organization of normality*, Oxford, Berg.

Shove, E. and Pantzar, M. (2005), “Producers and Practices: Understanding the invention and reinvention of Nordic Walking”, *Journal of Consumer Culture* 5, pp. 43-64.

Shove, E., Watson M., Hand M. & Ingram J. (2007), *The Design of Everyday Life*, Oxford, Berg.

Standardization mandate to CEN, CENELEC and ETSI in the field of measuring instruments for the development of an open architecture for utility meters involving communication protocols enabling interoperability M/441, FINAL REPORT, Version 0.7 – 2009-12-10, Smart Meters Co-ordination Group, http://www.nbn.be/nl/sm_cg_Finalreport_2009_12_10.pdf

Strengers Y. (2011), "Negotiating everyday life: The role of energy and water consumption feedback", *Journal of Consumer Culture* 11(3) 319–338.

The Climate Group (2008), SMART 2020 : Enabling the low carbon economy in the information age, Report on behalf ot he Global eSustainability Initiative, Creative Commons.

Ueno T., Inada R., Saeki O., Tsuji K., 2006, "Effectiveness of an energy consumption information system for residential buildings", *Applied Energy* 83, 868-883.

Verbeek, P-P. (2005). *What Things Do – Philosophical Reflections on Technology, Agency, and Design*. Penn State.

Verbeek, P.-P. & Slob, A., eds., (2006), *User Behavior and Technology Development*, Dordrecht, Springer.

Wallenborn G., Orsini M. & Vanhaverbeke J. (2011), "Household appropriation of electricity monitors", Journal of Consumer Studies, Special Issue on "Household Technology and Sustainability".

Wallenborn, G. (2007), "How to attribute power to consumers? When epistemology and politics converge", in *Sustainable Consumption, Ecology and Fair Trade*, E. Zaccaï (ed.) London, Routledge, pp. 57-69.

Wallenborn, G. (2008), "The new culture of energy : how to empower energy users ?", in *The Culture of Energy*, M. Rüdiger (ed.), Cambridge Scholars Publishing, pp. 236-253.

Wallenborn, G., Prignot N., Thollier K., Rousseau C., Van Cutsem A. (2007), "Energy-using products as embodying heterogeneous requirements", *WIT Transactions on Ecology and the Environment* 105, C.A Brebbia & V. Popov (eds.), WIT Press, pp. 145-154.

Wallenborn, G., Rousseau C. and Thollier K. (2006), Specifying household profiles for more efficient energy demand-side management, Final Report CP50, Belgian Science Policy (French report, English summary).

Warde, A. (2005), "Consumption and theories of practice", *Journal of Consumer Culture* 5, pp. 131-51.

Wilhite, H and Ling, R (1995), "Measured energy savings from a more informative energy bill", Energy and Buildings 22, pp145-155.

Wilhite, H. (2008) *Consumption and the Transformation of Everyday Life: A View from South India*, Basingstroke and New York: Palgrave Macmillan.

Wilhite, H. & Ling R. (1995), "Measured energy savings from a more informative energy bill", *Energy and buildings* 22, 145-155.

Wilhite, H., Shove, E., Lutzenhiser, L. and Kempton, W. (2000), "Twenty Years of Energy Demand Management: We Know More About Individual Behaviour But How Much Do We Really Know About Demand". ACEEE 2000 Summer Study on Energy Efficiency in Buildings.