Smart Metering and Consumer Feedback: What Works and What Doesn't

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ABSTRACT

Backed by rising energy demand, volatile oil prices, fears over security of supply and threat of climate change, smart metering in record time has become the most significant opportunity for designing and implementing effective residential energy efficiency programs in a growing number of western European nations.

In response to these pressures, EU and member governments are starting to mandate better automated meter management (AMM) as part of a mix of energy efficiency measures. But a move to energy data that is accurate while encouraging residential energy use reductions is a complex proposition. In the first place suppliers need to do this while at the same time differentiating themselves in a growing competitive marketplace where spurs for further growth and maintaining 'lean and mean' cost structures are often even more important. Another concern is the considerable doubt about the actual energy savings achieved through feedback, because the most effective channel for communicating energy information to the consumer is still unclear. Is it more accurate billing, a direct display, a personalized website, or something else?

Within the past few years, a growing number of European countries and other stakeholders started a broad range of innovative experiments to engage consumers in energy efficiency through smart metering. An overview of latest feedback insights is presented here. The most interesting insight thus far that the internet is not likely to become the favorite medium for energy feedback in Europe.

Introduction

Energy supply and household energy consumption are sociotechnical in nature: technology and behavior interact and co-evolve over time. Any attempt to change patterns of consumption has to take into account the interfaces between supplier, technology and consumer along with the ways in which data visualization can be improved.

Successful innovation of the informational aspects of smart metering is a promising way of developing a sustainable energy market. Smart meters offering more information to consumers and/or interaction with consumers could reduce household consumption of gas, heat and electricity in addition to offering other benefits. Backed by the European Services Directive (ESD), innovation of domestic metering and of feed back information related to smart metering is expected to 'boost' soon everywhere in the EU.

In 2007, to stimulate further awareness of end-user benefits and encourage the development of smart metering feedback technology, several European stakeholders took the initiative to form an alliance which they named the European Smart Metering Alliance (ESMA). This alliance aims to define and spread best practices in smart metering feedback for consumers across all European Member States. ESMA has been formed with partial funding from the European Union's Intelligent Energy programme. ESMA already has roughly 70 members from various sectors of the industry.

This paper guides the reader through the most effective consumer feedback techniques using smart metering which can be considered to favor the implementation of smart meters for lower costs and higher benefits. The basis for this paper is an ESMA-study on current smart metering experiences from both relevant literature as well as completed field trials. The purpose of this paper is to lead the reader to some clear principles for effective consumer feedback techniques. However, it is also important to stress that this paper sets out issues that are relevant to an efficient learning process, based on a search for best practices about consumer feed back from smart metering so far. This means that the data presented here are transient and evolving, therefore will need regular updates.

Smart Metering and Consumer Feedback

Traditionally, utility meter readings are not easily accessible for consumers, the information is displayed in kWh, often shown as a cumulative total, offering no ability for the consumer to access historical, or even instantaneous information. The positions of the meters are almost always determined by where the electricity or gas supplies come into the building.. The result is that the majority of consumers have difficulty in locating their meters as well as understanding the information when found. The introduction of smart metering in combination with feed back devices will change this. But not all benefits apply to all consumers. Some benefits only apply to a certain section of consumers, often the more vulnerable in society. The most common include:

- The end of estimated bills. Bills can be based on real consumption and can be sent more frequently. It is a major source of consumer complaint dealt with by the energy suppliers wherever in Europe. It will also eliminate debt bills that arise when estimated bills grossly underestimate actual consumption.
- rovision of historical data on bills. It will be easier to show consumers how their consumption compares with that in the same billing period of the previous year.
- Real time energy information from displays in communication with smart meters allows consumers to become more aware of their energy consumption. The growing ability for consumers to manage their consumption through pre-payment tariffs and/or regular monitoring of their energy use can result in savings on energy bills.
- The ability to switch between debit and credit without requiring manual intervention and/or the installation of prepayment meters.
- The ability to switch between energy suppliers more readily.
- The ability to alter energy consumption patterns to optimize time of use tariffs and lower bills.
- The ability to install a micro generation measure (DG/RES) and not require new metering arrangements.
- Possibility for prepaid/ postpaid schemes and easier credit, either by phone or internet for pay as you go meters.

In the presentation of the benefits of smart metering, the (potential) disadvantages should not be forgotten. One disadvantage is that smart metering leads to more automation, so there are privacy concerns and there is a potential for misuse of systems and/ or data by criminals, vandals and hackers. These concerns should be solved by good security. Another concern is the careless introduction of smart metering and related possibilities (e.g. differential tariffs) may lead to higher costs for some consumers or other form of decreased consumer satisfaction. But overwhelmingly it seems that these disadvantages can be overcome and will not outweigh the advantages. Careful piloting of both meters and tariffs is essential to minimize disadvantages.

Types of Feedback for Consumers

The international experience on consumer feedback covers a wide range of practices. These practices can best be understood in context by looking in terms of their contribution to the technique and type of information dissemination and data presentation as part of *the learning process* about the use of energy. Consumers receive information concerning their energy use, they gain understanding of what has happened through interpretation and finally, they act (change their behavior in some way). These elements do not always happen just like that, but each occurs when a person learns about energy-use. This paragraph divides feedback into four basic types, based on a mix of various degrees of:

- instantaneous and continuous information dissemination;
- type, quality and quantity of data presentation;
- interaction and control by the energy user.

Direct Feedback

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

Taking data directly from the meter also means that the information can be real time, much increasing its value and effectiveness. Recent developments in domestic communications provide paths for the data and destinations. For instance, the data can be transmitted via WiFi, Bluetooth, PLC, and Ethernet to a stand alone display, the TV or a home PC. All of these destinations allow the data to be brought somewhere convenient for the consumer. Data visualization through a stand alone direct display is in this respect most interesting, both TV and PC require consumers to make an effort to locate the information.

A well known example of direct feedback is the direct display on a monitor separate from the meter. Householders can look at the displays for instantaneous information and in some cases they can also set an alarm which is triggered when the load rises above a user-specified level. A potentially effective way to increase the consumer's awareness is to provide them with special in-house displays of readable, easy to comprehend energy use information, in a display design chosen by them. Once the consumers can see the changes in their energy use instantaneously on a display design, they are much more likely to act to reduce that consumption. In particular in the present and expected future rising energy cost environment. Parker, Hoak, Meir and Brown (2006) suggest a parallel with hybrid automobiles, where accumulating evidence suggests that feedback from dashboard-mounted displays allows drivers (e.g.. of Toyota's Prius) to improve their mileage as they learn from experience. The important reason for this is that drivers suddenly have an immediate feedback about how various aspects of their driving habits shape mileage.

Research-literature indicates savings from direct energy feedback devices range from 5% to 15%. Savings are typically of the order of 10% for relatively simple displays. There is also indication that high energy users may respond more than low users to direct feedback, because direct displays show up the significance of moment-to-moment behavior best.

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

Indirect Feedback

Important characteristics for indirect feedback are that consumers 1) have no direct access to actual consumption data, 2) respond to previous consumption behavior (which may have a lower information value), 3) need an optional feedback device, 4) need a level of commitment regarding regular use and interaction, and 5) have to rely on information being processed in some way before reaching the energy user. Examples of indirect feedback are frequent (e.g. day-to-day) feedback through an interactive webpage on PC, e-mail, SMS or periodic/ frequent informative billing, based on smart meter readings with a combination of:

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

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

Better billing, when combined with an in-house display, can contribute to consumer awareness of energy and that environment that may help them to make reduction decisions. Information alone will not deliver energy savings; however, once consumers are aware of their usage, in particular in times of increasing energy costs, it is reasonable to believe that this is much more likely to reduce usage. The likelihood of this will almost certainly increase if traditional energy efficiency advice is adapted with the knowledge that consumers are aware of their energy usage.

Pre Paid Systems

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

Nevertheless, from an energy saving point of view, modern pre paid systems have the potential to be much more than just a traditional option to low-income consumers in general. Research-literature indicates that savings to date for all keypad consumers are estimated to range broadly from 3% to approx. 15%.

Time Sensitive Pricing

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

- The first one is based on a market equilibrium (spot price) and should ideally correspond to the electricity generation costs;
- The second one is regulated as a natural monopoly and normally reflects T&D losses and some other costs.

This is relevant, because in some countries such as the Nordic countries, the consumers receive separate bills for this. In this report, the expression "tariff" is related to distribution network tariffs, not electricity price. In general, three broad types of tariffs can be distinguished:

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

2. **Actual cost** tariffs require consumers to pay, in each half hour period, the actual cost of electricity. The price is usually known shortly before the time of use. Consumers are alerted to these prices through the meter display.

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

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

Electricity tariff structures, such as time of use pricing, critical peak pricing and real-time pricing are important in those parts of the world with:

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

The main purpose of time sensitive pricing and load control is not end use energy savings. They may even increase energy end use. The point is that total energy consumption in the whole system is in most cases reduced by responding to market prices and system requests, because the less efficient generating plant that is used to meet peak demand is required less often. That is a goal of any reasonable energy saving policy. The primary energy savings from demand response depends on what peak generation resources are not required.

In Scandinavian countries and in some other countries like France, there is significant electrical heating and therefore a lot of potential for <u>real time pricing</u>. In other parts of Europe, there seems to be less need for load-shifting among domestic consumers. Moreover, most households have gas heating, while almost all the rest use off-peak electricity, oil or solid fuel for their heating. In short, opportunities for reducing peak usage are limited and there are equity concerns. Nevertheless, time-of-use or real-time pricing may become more important as part of more sophisticated load management and as more air-conditioning and/or distributed generation comes on stream. Real time pricing methods may enable a better use of renewable, intermittent sources of energy, in particular the intermittency of large wind farms.

The Role of Load Management

The term load management is probably known in various markets under other names such as demand response, direct load control, demand side management, peak load control, etc. This can be exercised either indirectly, as described above, when the consumer makes choices in line with time-sensitive pricing options offered by the utility, or through utility-controlled approaches (direct load control). Direct load control only involves feedback in an automated sense. For example, changes in demand on the electricity system can trigger the switching-off or on of appliances, or, when household renewables are available, their output can be matched to the use of appliances such as washing machines.

There is a debate as to the extent to which demand response methods lead to carbon emission reductions, either via reduced demand or the reduction in use of high carbon intensity generation plant at peak periods. The benefits in terms of security of supply are more clear. Direct load management can have other effects if combined with the use of smart appliances, building services and household renewables. The ability of a washing machine, for example, to only operate when there is a low carbon electricity supply available can increase the carbon abatement possibilities significantly.

Lessons Learned from Experiments and Field Trials

In the last couple of years, there has been growing interest in the potential benefits of introducing smart metering and how this should be done. It has become a 'hot' topic in countries such as UK, USA, Canada, Netherlands, Italy, Australia and the countries of Scandinavia. Despite these recent developments, there is still relatively limited specific evidence from recent use of smart metering to quantify energy savings in households. Studying the effectiveness of feedback on gas and electricity consumption does not have a long scientific tradition. Most evidence so far is based on small-scale trials and only very few have been longitudinal to judge whether the response is likely to last or can be built upon.

Another complicating factor is the difficulty of comparing these field trials. All contain a different mix of elements such as sample size, housing type, additional interventions, financial influences, household composition, feedback frequency and duration. Further, recorded feedback savings can dramatically differ according to the technology under consideration, the institutional and cultural background (lifestyles) and of course climatic conditions against which the study takes place, the quality of feedback information and the way in which studies are conducted. And last but not least; the most effective feedback techniques are likely to evolve over time. Home ICT is evolving very fast. In a landscape where all appliances and multimedia applications will be linked together, innovative techniques like pop up messaging on the TV set when on, could be more effective than a specialized screen displaying the same messages all the time.

Nevertheless, this guide is an attempt to draw lessons from what is known about the effectiveness of feedback to householders regarding energy consumption behavior. As mentioned before, it is expected that within a relatively short period of time many currently running experiments will deliver new results, insights as other experiments begin. So this section is about basic understanding of the factors that influence the impact of smart metering and feed back on consumer demand.

Some interesting lessons learned from recent experiments and reports on feedback so far, are worth mentioning here.

- **Key finding 1: Energy feedback: handicapped by low interest of consumers.** Almost all studies show that household energy use is largely invisible to the user. People tend to have only a vague idea of how much energy they are using for different purposes and what sort of difference they could make by changing day-to-day behavior, reducing waste or investing in efficiency measures. In 2005, Dobbyn and Thomas clearly expressed the traditional high degree of complexity in successfully communicating with consumers on the issue of energy and energy conservation:

  "Energy and power are not terms within the natural language of mainstream householders. Gas and electricity operate at the level of the subconscious within the home. Whilst there does seem to be some latent cultural guilt about the notion of waste, there appeared to be virtually no sense of being able to actively and significantly reduce energy consumption in the household. Providing final consumers with more information may simply tell them that they spend a small and acceptable part of their income on energy. However, it is clear that, if they decide that they do want to reduce their consumption, they will need better information to enable this."

- **Key finding 2: Measuring of 'feedback savings' is difficult.** Darby (2006) and Owen and Ward (2006) analyzed a variety of feedback types and smart meters, and stressed the problems associated with trying to measure associated energy savings over many years. Darby identified the problem that participants in trials sometimes knew they were being observed and this could result in them behaving differently over a short timescale ('Hawthorne effect'). Another aspect is the degree of interaction and motivation by an "energy efficiency enthusiast" which could also influence the outcome. Recent trials tried to address this effect through executing larger samples and controlling for the Hawthorne effect; allowance needs to be made for the human intervention and timescales over which these are measured.

- **Key finding 3: Persistence of feedback: after three months.** According to Darby (2006), persistence of savings will happen when feedback has supported 'intrinsic' behavior controls – that is, when individuals develop new habits – and when it has acted as a spur to investment in efficiency measures. Where feedback is used in conjunction with incentives to save energy, behavior changes may fade when the incentive is taken away. Generally speaking, a new type of behavior formed over a three-month period or longer seems likely to persist – but continued feedback is needed to help maintain the change and, in time, encourage other changes. It is uncertain how much this can be expected for smart metering, because there is little experience of using smart metering as a component of other energy savings measures. The design and deployment of the user display – the interface between utility and consumer – will be crucial in determining the effectiveness of any smart metering system. Without a good data visualization and/or display, the only change in feedback to the consumer will come through changes in billing.

Insights of Feedback (Do's and Don'ts of Feedback)

Information measures on energy consumption cover many different methods, techniques and technologies in generating feedback on domestic energy behavior. Feedback methods include giving consumers instantaneous, historic or comparative feedback, prepayment / pay-as-you-go, or any or these in combination with other types of information. Technologies include advanced billing, displays, internet etc. Based on an international literature scan in 2007, Jonkers, Janssen and Gelissen summarized their conslusions regarding the use of methods and techniques for feedback in The Netherlands. Some interesting findings are:

- Targeting seems to be effective: adding a high but reachable target to the feedback information can raise energy savings;
- Peer group pressure seems to be effective to raise energy savings;
- Negative feedback (such as "your energy consumption is higher than targeted"), can have a 'killing' effect on new efforts to save energy;

- Historic feedback seems to be more effective than comparative or normative feedback;
- Feed back information focusing on wasted energy consumption seems to be more effective than information on necessary energy consumption;
- There seems to be little willingness to pay extra for feedback devices;
- Internet is not likely to become the most favorite medium for feedback.

The insight last mentioned above is particularly interesting for The Netherlands, because the feed back applications developed by energy suppliers tend to become internet based in the first place. From an energy saving point of view, this seems to be a false choice.

These finding accounts also for other European countries, according to recent pan European market research on the role of information and technology and consumer preferences regarding the use of feed back technologies in facilitating energy saving behavior.[1] The next table shows clearly that that internet probably is not considered to become the most satisfying medium for energy feedback, accounts also for many other European countries.

Preferred Communication Technology for Receiving Smart Meter Feedback Information (More Options Possible, Boldface Indicates Highest Score)

Country involved in market research	Information on screen / direct display	More detailed bills	Personalized web page(s)	Telephone services
Finland	**68%**	46%	34%	10%
Norway	**54%**	29%	32%	10%
Sweden	**49%**	28%	39%	5%
Denmark	**58%**	29%	41%	10%
Netherlands[2]	**39%**	25%	23%	10%
France	**57%**	53%	28%	9%
Germany	61%	**66%**	32%	5%
Great Britain	59%	**61%**	30%	20%
Spain	50%	**73%**	29%	23%
Portugal	22%	**32%**	18%	5%
Average	55%	**57%**	30%	11%

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

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

This surprisingly low preference for information through a personalized webpage is even clearly visible in the European countries with the highest levels of internet penetration, such as

[1] This great European study, called 'Turning concern into action: energy efficiency and the consumer' was conducted by Future Foundation and TNS UK in combination with Euro barometer and commissioned by LogicaCMG, a major international force in IT and business services based on a computer assisted telephone interviewing methodology in 10 countries. A sample size of 1.000 individuals per country was used, resulting in a total sample of 10.048, weighted to ensure accurate representation. The 10 countries included in the survey were: Denmark, Finland, France, Great Britain, Germany, Norway, Portugal, Spain, Netherlands and Sweden.

[2] Netherlands is a notable exception, because also a considerable percentage of the respondents chose 'none of these'.

the Scandinavian countries. Most consumers here are experienced users of the internet and often more inclined to carry out a wider range of tasks on the internet, including bill payment. Research carried out by Nvision in 2007 found that 92% of Norwegians, 79% of the Swedes and 68% of the Danes had paid a regular bill online in the past six months, compared with a European average of 23%.

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

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

Conclusions

The broad European preference for direct displays and more detailed billing and not for personalized web pages is by far the most surprising outcome so far. This indicates that consumers point at an important shortcoming of web based applications: there is a latent but strong desire of consumers to get information on energy consumption that is immediate, instantaneous and continuously visible. Consumers feel that this is important, because domestic energy use is invisible to the user. Most people realize that they have only a vague idea of how much energy they are using for different purposes and what sort of difference they could make by changing day-to-day behavior or investing in efficiency measures. Hence the challenge of feedback is making energy more visible and more amenable to understanding and control.

Backed by these results it appears that, while internet and online billing can provide a useful interactive feedback service and can incorporate analysis and advice, they are unlikely to be a satisfying substitute for energy savings in households. Consumers simply need to see what is happening to consumption, without having to switch on an optional feedback service.

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