USmartConsumer: real-time smart meter feedback to kick-start consumer interest

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Abstract

In line with European legislation regarding energy efficiency, considerations for large-scale smart meter rollouts are taking place in a growing number of Member States. Smart meters are hypothesized to contribute to energy efficiency, if they come publicly accepted and in line with truly engaging and empowering smart metering services. To help meeting these crucial preconditions, the EU-networking and dissemination project USmartConsumer encourages European market players and households to benefit from smart metering, by promoting its potential to save energy. The latest contribution in this respect comes from the Netherlands. A large and multiple consumer behaviour literature review and pilot program was recently undertaken by order of the Dutch Government to deliver input for a balanced Parliamentary large-scale rollout decision of smart meters in the Netherlands. Involving thousands of households, this pilot program is among the largest scientific smart metering trials conducted worldwide to date. This paper presents a review of the main results of the trial programme in the Netherlands and aims to share practical lessons on consumer experiences as well as more favourable conditions for market actors. Like in similar trial programmes in the UK and Ireland, it has been concluded that smart metering in combination with direct feedback, in-home displays in particular, can lead to considerable and persistent household energy reductions. More sophisticated web-based services on PC, tablet and smart phone are also potentially powerful to help reduce energy demand, but in practice more so with already committed and technology minded subsets of the population. Due to a lack of engagement amongst less committed or skilled consumers, as seen in some pilots, it is suggested that opt-in websites or apps might not be appropriate for all end-users as a substitute for in-home displays, but rather could be offered as a complementary option. When motivating the large scale rollout decision to Dutch Parliament in June 2014, the Dutch government promised to ensure a broad product range of smart metering services for all population groups.

Introduction

Backed by rising energy demands and fears over security of supply and climate change, smart metering is rapidly gaining momentum across the world. Europe is expected to become a world leader of this development, thanks to the European Services Directive (2006), Third Energy Package (2009) and Energy Efficiency Directive (2012). The Energy Services Directive laid the foundation for a European wide legislation for smart metering, by requiring individual energy meters and standards for frequent and understandable energy bills. The Third Energy Package accelerated the penetration of smart electricity metering in EU by setting a target of at least 80% of all households to have a smart meter by 2020, given a positive economic assessment. Last but not least, the present Energy Efficiency Directive connects the smart meters directly to dynamic pricing and improved feedback programs and empowers smart meter and consumer feedback regulation.

Although serious considerations for large-scale smart meter rollouts take place in a growing number of Member States, public support and hypothesized energy savings should not be taken for granted however. Smart meters are generally hypothesized to contribute to increasing consumer involvement and enable effective household energy savings, if smart meters become publicly accepted and be combined with empowering energy management services. This paper aims to contribute to the already existing evidence based literature to back this statement up.

To help Member States meet these preconditions, the USmartConsumer project was initiated by several European energy agencies, market players and consumer associations.[1] The project's aim is to contribute to public support for smart meters and beneficial market conditions in terms of transparency and confidence for innovative smart metering services market players in the Member States. This is in the main being done through market analysis updates of smart metering services developments in the EU, initiating promotional consumer engagement activities in the partner's Member States and -last but not least- dissemination of new evidence in the smart meters potential to save energy, delivered by scientific based consumer behaviour trials in Europe.

Being part of the USmartConsumer dissemination activities, this paper elaborates on the research evidence for smart metering based energy saving potentials, coming from the Netherlands. Following the United Kingdom and Ireland, the Netherlands are the third Member State in which realistic consumer behaviour smart metering trials in combination with multiple innovative energy management tools across the country have been undertaken. On request of the government, the Netherlands Enterprise Agency in cooperation with some of the larger network operators developed a monitoring program based on both literature reviews of previous consumer behaviour experiments with smart meters as well as new pilots with various smart meter feedback interventions between 2011 and 2014, all primarily directed at reducing domestic energy consumption. Involving thousands of households, the Dutch pilots are among the largest scientific smart metering research trials to test consumer responses to different forms of feedback instruments, conducted worldwide to date.

This paper starts with a brief introduction on smart metering and a short overview of the legal rollout situation in the Netherlands. The main section of the paper collates and reviews the outcomes of the previous experiments as well as the latest pilot findings in the Netherlands in order to build on the wider international literature to identify the interventions that have proved most effective in reducing consumption. The paper concludes with a brief overview of the key lessons learned on how such interventions can best be delivered to the European consumer.

By elaborating on the recent experiences in the Netherlands, the USmartConsumer project partners hope to provide practical lessons to stakeholders in other Member States who are still searching for evidence about the smart metering energy savings potentials. Additionally, the policy approach adopted in the Netherlands to learn together with relevant stakeholders about end-user engagement and subsequently arrive at a better rollout strategy and more promising prospects for energy savings, could inspire other Member States to develop regulatory frameworks that are more likely to contribute to consumer satisfaction and energy efficiency. The monitoring program in the Netherlands provided relevant input for the Government to underpin the Ministerial Decree for the large-scale roll-out of smart meters in March 2014.

SMART METERING ROLLOUT IN THE NETHERLANDS

In line with European legislation, the Dutch Government and Parliament agreed in 2011 to start a phased rollout of new electricity and gas meters for consumers and small businesses.[2] These energy meters, widely known as smart meters, are the next generation of meters to replace existing electro-mechanical meters. Smart meters can potentially offer new benefits, both for the individual electricity and gas consumer and for the network operators and energy suppliers. For network operators, automated recording of actual energy usage over short intervals and automated communicating of metering data to the network operator will facilitate more cost-efficient network operations such as eliminating the need for manual meter readings. Electricity suppliers will be able to introduce new pricing arrangements for consumers and support more efficient use of energy (i.e. time-of-use tariffs).

But the smart meter also offers potential advantages directly to the consumer.[3] Smart meters can put an end to estimated billing (people will only be billed for the energy they actually use) and allow easier switching of supplier to get the best deals. However, the most immediate consumer benefit of the smart meter is the ability to receive more frequent and more detailed feedback information on how much energy is being used. With regards to the more frequent feedback information, the smart meter offers basically three options to the Dutch consumer.

Firstly, Dutch consumers with a smart meter will receive next to their annual bill, several interim consumption and cost statements from the energy supplier, hereinafter referred to as energy usage statements. The energy usage statement is established in Dutch legislation and subject to minimal requirements, in line with European legislation (Ministerial Decree Energy Usage and Cost Statement, 2011). This statement must provide insight into the actual consumption at actual energy prices and must compare this to previous consumption periods and to comparable end users. Energy suppliers are obliged by Dutch law to offer the energy usage statements at least 6 times a year to every customer with a smart meter. The bi-monthly statement must be delivered actively, either by regular mail or as a PDF attachment to an email. It is not sufficient to merely provide the report passively on the supplier's website.

Secondly, if so desired by the consumer, the smart metering data can also be sent on a daily basis to the energy supplier – or another smart metering service provider – for additional and more detailed energy consumption analysis over the previous days, weeks and months in combination with tailored energy reduction advices.

Finally, consumers will be able to receive energy consumption information directly and in (near) real-time by connecting

1. Project funded by Intelligent Energy Europe (IEE 13-590) with participants from Austria, Finland, Germany, Italy, Netherlands, Poland, Spain, United Kingdom.

2. In 2009, the so-called Energy Package was established at the European level, which stated, amongst other things, that under other conditions in 2020, at least 80 % of households must have fitted a smart meter.

3. Where this paper refers to households or consumers, it also refers to the small business consumer throughout.

a wireless transmitter or 'bridge' to the so-called P1-port on the smart meter for an in-home display or online application on the consumers own PC, laptop, tablet or smart phone.[4] Providing customers with products and services to better monitor and manage energy consumption is by law considered to be a market responsibility in the first place. To support the market development for real-time smart metering services, functional requirements for the smart meter have been established in legislation.[5] The grid operators have established technical specifications for the P1-port in a so-called companion standard.[6] Dutch smart meters are thus equally designed to facilitate energy efficiency by empowering consumers with more detailed, accurate and timely information regarding their energy consumption and costs. As a consequence, real-time monitoring products and services are now emerging on the Dutch market.

LEGAL CONSIDERATIONS FOR SMART METERING ROLLOUT

The Dutch Government's objective is to have the next generation of electricity and gas meters offered to all residential and small business customers and installed by at least 80 % of the population by the end of 2020 (Ministerial Decree Large-scale Roll-Out Smart Meters, 2014). Residential and small business customers in the Netherlands are not obliged to accept a smart meter. Customers who object to the installation of the smart meter can either have the communication of the smart meter deactivated, or even refuse the installation of the smart meter. If the meter is administratively deactivated, the smart meter will actually function like a traditional meter. In case of refusal, the old electricity meter (and gas meter) will remain in place, and the meter reading cannot be done remotely. In case of acceptance, the consumer can choose to have the smart meter read remotely at all times or limited to specific situations appointed by law (annual bill, bi-monthly energy usage statements, when switching supplier or moving house).

It was agreed in the Dutch Parliament in 2011 to introduce the smart meters according to a two-phase rollout-approach, to begin on a small scale in 2012 until 2014.[7] During this initial rollout period, the smart meter was only installed in the event of new construction and large-scale renovations and in the case of malfunctioning existing meters. The consumer was not charged for this type of installation/replacement.[8] The purpose of this phased rollout approach was to meet European legislation and to gain crucial rollout experiences and information on consumer responses to provide input for the parliamentary decision on the second phase, the large-scale rollout between 2015 and 2020.

Among the imperatives to support a parliamentary decision on the large scale rollout of smart meters in the Netherlands, was the need for a scientific verification of the presumed residential energy savings potentials as quantified in the national Cost-Benefit Analysis (CBA) for the introduction of smart meters, executed in 2010 (Van Gerwen et al., 2010). In this CBA it was estimated that the smart meter, in combination with sophisticated forms of feedback interventions, can potentially result in average savings of 6.4 % for electricity and 5.1 % for gas. Energy saving is therefore expected to be among the most important benefits for society, resulting from the introduction of smart meters in the Netherlands.[9]

To substantiate this, the Minister of Economic Affairs committed to the House of Representatives to provide more insight from new pilots in the true savings from the smart meter in combination with various feedback systems during the small-scale rollout. The coordination of this pilot program was assigned to the Netherlands Enterprise Agency.[10]

The following sections review the overall findings from the national research executed to date in the Netherlands to identify the interventions that prove most effective in reducing consumption from smart metering services. The first section presents a review of the existing research literature related to earlier smart metering consumer behaviour experiments in the Netherlands. After that the pilots conducted as part of the small-scale rollout, executed by the Dutch network operators Liander and Stedin, will be reviewed in more detail. In reading these sections, it should however be noted from a general scientific point of view that experiments and pilots often tend to relate to relatively small populations, with a chance of self-selection amongst participants who know they are being studied, also named the Hawthorne effect (Darby, 2006). The results of this pilot program should therefore be seen as indicative, rather than representative for the entire Dutch population.

Literature review of earlier Dutch smart metering experiments

In the Netherlands, approximately five studies have been conducted to better understand how consumers react to improved feedback from smart meters, prior to the small-scale rollout. These studies are briefly explained below.

Energy supplier Oxxio was the first, in 2008, to conduct trial research on the effectiveness of savings achieved with the smart meter, in combination with non-realtime (also called indirect) feedback through an online self-service platform (Jonkers et al., 2011). This supplier based web service, called MijnOxxio, provided customers with additional insight into their (historical) energy and gas consumption, as well as information on tariffs

4. The traditional mechanical and digital pulse meters also provide the option for real-time information on household energy consumption. These older generation meters use optical 'readers' which can also be attached to the electricity meter and possibly also to the gas meter, instead of a special connection option (also called a P1 port). However, such a system is rather prone to errors compared to when smart meters are used.

5. In January 2012, the Ministerial Decree on remote-readable metering devices (hereinafter referred to as: the Decree Meter Requirements [*Besluit Metereisen*]), came into force. This Decree placed minimum requirements on the smart meter, by establishing the functionalities that are deemed important from a social perspective and in view of privacy and security.

6. These requirements are included in the so-called Dutch Smart Metering System Requirements (DSMR)

7. When reference is made to the smart meter, it also means the gas meter, in addition to the electricity meter, throughout. With the installation of the new electricity meter, the gas meter – if present – is also replaced and then connected to the new electricity meter (in a wired or wireless fashion). The smart meter thus applies, in general, to both electricity and gas.

8. Smart meters replacements on the consumer's request took place in return for a reasonable network operator fee.

9. The savings referred to in the KEMA report are based on an expert assessment of a realistic potential based on literature studies. The KEMA report herewith states emphatically that it does not (merely) involve the introduction of a smart metering infrastructure or display, but that use of this metering infrastructure and the method of feedback also have a major influence.

10. The Netherlands Enterprise Agency succeeded the NL Agency as the implementing body for policy regarding sustainability, innovation, and international business and cooperation for the Dutch national government.

and costs, through a personal web page on their own PC/laptop. The Universities of Amsterdam and Maastricht conducted research amongst 2,513 of Oxxio's clients for a period of two years. The researchers found that clients who used the web application, consumed on average 1.5 % less electricity and 1.8 % less gas compared to other Oxxio clients with a smart meter, but without using the website.[11] Three-quarters of the examined group still visited their personal web page after a year to obtain insight into their in-home changes in consumption.[12] These savings were lower than the researchers had anticipated. The researchers had assumed that the savings with new smart meter users would potentially be higher, since the clients that were studied also had a smart meter for a longer period of time, and likely formed part of a select group interested in energy savings.

In 2009, energy supplier Nuon and Eindhoven University of Technology conducted a small trial to investigate the development of consumption behaviour amongst consumers with a smart meter and a real-time in-home energy display (UC-Partners et al., 2009). The trial involved 40 households with a smart meter, where one half received a real-time energy display and the other half did not. Both groups were equal in terms of composition, domestic environment and environmental motivation – after scientific selection – and were given the same instructions and recommendations for achieving savings.[13] After four months, the researchers found that a considerably higher portion of participants with a display appeared to be able to save energy, compared to households without a display.[14] The display group also succeeded in saving considerably more energy (average of 9 % for electricity and 14 % for gas) than the group without a display (3 % for electricity and 2 % for gas, respectively). To conclude, the display group expressed more positive feelings about the test and complained less about the (time) effort. After some time, the participants started to understand their own consumption patterns better and felt less need for daily consulting of the system. The participants without the display reported less positive experiences, and considered their participation to be more of a hassle. The researchers concluded that a real-time display can contribute significantly to willingness to reduce energy consumption.

In 2010, the previous experiment was continued on a ten times larger scale, under the name West Orange, in the context of Amsterdam Smart City (Noort & Van Ossenbrugge, 2011). Amongst approximately 400 households – mostly home owners – researchers from the University of Amsterdam again saw an increased energy awareness and development of energy-saving behaviour. According to the researchers, the in-home display ignited a pre-existing need amongst consumers to monitor energy consumption as well as the effects of savings measures. This resulted in a significant reduction in energy consumption, 4.5 % for electricity and 4.6 % for gas, which was not observed in the control group.[15] Moreover, the researchers stated that these savings only represent the lower limit, because not all displays functioned to the best possible extent. Another finding was that the savings were mostly the result of simple behavioural changes that required little or no investment of time or money (low cost quick-win). Longer-term investments aimed at energy savings, were not or hardly taken into consideration.[16] Despite the prototype technology and aesthetics of the display, the majority of participants (58 %) were interested to have such a device at their disposal.

Research by Delft University of Technology, on the effectiveness of in-home displays between 2008 and 2012, highlighted the relevance of habit formation (routine use) with the feedback system for persistent savings in the longer term (Van Dam, 2013). In this experiment, researchers installed a real-time electricity monitor which provided information on actual consumption, daily consumption and a comparison with a savings target, at 54 households (with a traditional meter).[17] After four months, the households were split into a group of 28 households that returned their display (in exchange for €25) and a group of 26 households that wanted to keep the display. After 11 months, it became evident that the savings achieved in both groups, in the first four months, declined.[18] With the households that returned the display, the previous savings of 3.9 % dropped to a negative savings of -1.0 % (a consumption increase over the original level of consumption). With the display group, the savings also decreased, depending on the extent to which the display was used routinely. Irregular users of the display (12 households), experienced a 6.3 % level of savings after 4 months, dropping to 1.7 % after 15 months. The users who kept to their daily routine of consulting the display (most common use was the 'bed-time' base level check) also experienced a reduction in savings, but maintained significant savings levels of 7.8 % after 15 months. The survey pointed out that the magnitude of savings depended on the persistence and intensity of households' use of the feedback device. It was also concluded that an energy display is only an effective trigger in the long term amongst consumers who are more receptive to energy savings (Van Dam, 2010). Furthermore it is emphasised that the feedback should not be limited to a single user alone as is often the case with (mobile) web based services. The importance of family dynamics, as a stimulus for the acceptance and use of home-energy management systems, should not be underestimated (Van Dam, 2013). An energy display at a convenient location in the home, which is amenable to all members of the household, was found by this study to trigger family discussions and an increased chance of acceptance and persistent use of the energy display.

11. A comparison to households without a smart meter, as a control group, was not included in this study, which means that statements could not be made in this respect.

12. The frequency, with which the personal area of the website was visited, is not known.

13. The participants were scientifically selected from a large group of 50,000 households and were divided into two groups by way of invitation (1,000 households) and questionnaires (approximately 200 households), equally on the basis of environmental motivation and behaviour.

14. In the display group, 81 % achieved savings for electricity and 100 % for gas. In the group without a display, 47 % succeeded in achieving savings for electricity and 65 % in achieving savings for gas.

15. The control group consisted of approximately 3,000 households, drawn randomly from Nuon's client base in the Amsterdam region.

16. This observation may also be due to the fact that the majority of the participants reside in homes that are better insulated (wall insulation and double glazing, in particular).

17. It involved an electricity display named Wattcher, manufactured by Innovaders in Amsterdam. All participants were also offered to use an online advisory and registration system for processing of the meter readings that were taken individually. Most participants had a traditional electricity meter.

18. The evolution of consumption for the different groups is based on the meter readings provided by the participants, divided over 5 research periods. Since many errors were made during this process, the study of the effects was eventually conducted with 54 of the original 264 participants.

Results of the Dutch small-scale rollout pilot program

The previous smart metering experiments, described above, did not fully represent the current range of feedback methods and also do not relate to the consumer behaviour responses from all population groups. For example, they did not include sophisticated web based services on modern mobile media such as tablets and smart phones. In addition, most participants in the previous experiments tended to be generally home-owners with higher incomes and/or education levels and more interested in energy savings. Consumers from lower income groups, were generally not represented in these studies. In order to draw conclusions on modern media and fuel poor consumers as well, two pilots were conducted during the small-scale roll-out phase by the network operators. The main results of both pilots are reviewed below.

ENERGY MANAGEMENT APP FOR SMARTPHONES AND TABLETS

In 2014 grid operator Liander published the results of a 12-month consumer behaviour pilot, using a smart meter and a feedback app for smart phones, named 'Energy Warriors' (Liander, 2014). The energy management app provided live data on energy consumption in energy-units and in costs for electricity and gas. The app also enabled comparison of the household's consumption against previous periods or with a reference group of households (benchmarking). Finally, the app provided the option to set a savings target, to continue the incentive for consumers to lower their energy consumption.

The field trial started in June 2012, and included approximately 500 residents in the city of Arnhem, mainly home owners with a higher income, education and environmental motivation. A quantitative consumption change measurement based on meter readings amongst approximately 330 participants, showed an average reduction in consumption of 3 % for electricity and an average of 4 % for gas over a year, compared to the forecast consumption for this group. The forecast consumption of electricity and gas was based on quantitative research through a historical trend line analysis, where this consumption is compared to the smart meter measurements. The results of the effects measurement were checked by the independent research agency IVAM, using a multiple regression analysis (MRA) and the non-active participants as a control group check.[19]

The accompanying consumer experience survey, covering approximately 160 participants, found that the app had a high effect on raising energy awareness, but a relatively low effect on the energy-saving behaviour. A mere 18 % drew a connection between the measures that were taken and the provided app, 35 % did not see any connection, and 47 % only saw a partial connection. According to the researchers, this could be due to the already higher environmental motivation amongst most participants, which meant that many measures were already taken in the past. Also, the frequency of using the app dropped substantially during the pilot period: by the end of the pilot period approximately two-thirds of the respondents used the direct feedback app only once a month or even less frequently.

As seen in the other direct feedback pilots, most energy saving measures had a low cost/quick-win character. Longer-term investments were less taken into consideration.

ENERGY DASHBOARD FOR FUEL POOR CONSUMERS

Network operator Stedin, in cooperation with housing corporation Woonbron and the City of Rotterdam, published the results of another trial investigating the consumer responses to a smart meter in combination with a real-time energy dashboard among 140 households in the low rental segment (Stedin, 2014). This trial involved an in-home energy monitor for smart meters with a non-numerical dual fuel user interface, resembling a car dashboard. Users can obtain insight into changes in consumption at a glance, both in real time and for past periods (month and year) and can compare this information with a self-set savings target and/or previous consumption periods. This population group was targeted to build more understanding of how to best support the fuel poor during the smart meter roll-out.

Following a local information campaign, approximately 325 residents of rental homes in the Rotterdam residential area IJsselmonde, mostly insulated in a moderate to poor fashion, were invited for the pilot. The interest to participate in the pilot seemed high with this target group, which was previously thought of as difficult to motivate. Nearly half of the invited residents wished to participate in the pilot, and of these nearly 90 % completed the pilot, which lasted nine months.[20] Furthermore, a majority (60 %) of the participating households used the energy dashboard actively throughout the pilot and succeeded in achieving substantial energy savings; average of 5.6 % for electricity and 6.9 % for gas, compared to the multi-annual historical consumption data. However, more than half of the participating households achieved savings of more than 10 % on electricity and gas. Since roughly half of the participants developed a daily or weekly habit to use the energy dashboard which continued even after nine months, it appeared that many users experienced continuous reinforcement and continued to take up the challenge to consult the energy dashboard to persist in their energy savings.

Additional consumer research at the beginning and at the end of the pilot, which involved 75 % of the participants, reflected a high recognition for the PowerPlayer energy dashboard. Three-quarters of the respondents experienced the PowerPlayer display as a 'missing link' to activate consumer interest and engagement in in accessing energy information from smart metering. Most respondents highly appreciated the energy dashboard because the resemblance to a car dashboard for electricity (and a gas burner for natural gas) was well understood. Most participants also found the PowerPlayer easy to operate and that the display did not contain any superfluous functions.[21] This appreciation is even more evident from the fact that 70 % of respondents wanted to recommend the

19. IVAM is an independent research and consultancy organisation in the field of sustainability and is specialised in statistic scientific research, amongst other things; originating from the Interfaculty Department of Environmental Science [Interfacultaire Vakgroep Milieukunde] at the University of Amsterdam.

20. Of the approximately 325 households that were approached, 142 households (45 %) participated in the pilot. Of the initial 142 participants, nearly 90 % (roughly 125 households) completed the pilot programme. In addition, approximately 75 % of the participating households (105 households) also contributed to the final survey.

21. Some older participants felt that operation was still rather difficult. The older generation formed a relatively large part of the pilot participants (23 % of the participants were older than 70).

dashboard to others. As seen in other real-time feedback studies, most savings measures required little or no investment of time or money. The most frequently taken savings measures were turning down the thermostat, turning heat off in unused rooms, switching lights off in unused areas and unplugging chargeable devices from outlets, avoiding stand-by mode and also cutting down on showering time. Longer-term measures directed at energy savings were (expectedly) not or hardly taken into consideration.

Finally, as already referred to in the consumption change evaluation, the frequency of use of the energy dashboard display did not see as great a decline over time as has been seen in some other trials. After nine months, more than half of the respondents still checked the energy dashboard every day to every week. The decline in the use of the display amongst the active users seemed to be the logical result of habituation, the learning effect and the 'running out' of (behavioural) quick-win measures. As consumption patterns continue to become more familiar to the end-user, the need for frequent display consulting and initiating behavioural measures becomes less. Then the emphasis turns from (daily to weekly) consumption monitoring and initiation of measures, to a (weekly to monthly) habit of consumption checking and consolidating of the lower consumption.

Evaluation of the Dutch smart metering experiments and small-scale pilot program

Even when taken into account the relatively small-scale nature of the experiments and pilots and the risk of self-selection and influencing through trialling, it appears that smart meters with sophisticated feedback, can have a significant impact on in-home energy consumption and to the savings to be achieved with it. The opportunities for savings look most promising in the case of real-time feedback. Even so, long-term success is not guaranteed: engagement and habit formation through continuous feedback reinforcement are also important for persistent savings. Only if the feedback instrument meets the practical user preferences and the functionality and data presentation (interface design) match with the consumer's interests and capability, persistent savings are more likely.

At the hardware level, this indicates that advanced web based applications on PC, tablet or smart phone will have a better chance of succeeding with already committed, technology-oriented and internet savvy consumers. For these consumers, comprehensive functional data analytics and multiple graphic presentation options, in combination with the ease of (mobile) multimedia devices, will offer the desired added value for habit formation to use the system. As seen in the study by Oxxio, many participants – customers with a predominantly higher education and environmental motivation – also visited the personal section of the website after a year, to keep detailed track of their in-home energy consumption progress.

On the other hand, advanced web portal applications appear to require much more effort and discipline for persistent use amongst less committed consumers or those who are less technology minded, or simply those who can't commit to much effort. It became evident from the PowerPlayer study that a functional simple physical display, but with an intuitive and self-explanatory user interface design, were important for the persistent use of the real-time feedback system. For these consumer groups a simple yet visually appealing physical energy monitor will be the logical first step to activate consumer interest and engagement in accessing energy information from the smart meter, due to the greater accessibility of the energy data.

Next to the practical user preferences and balanced functionality and data presentation (interface design), the Technical University of Delft also demonstrated that social interaction within the household (family dynamics) will be crucial to the reinforcement of engagement and persistent savings.

A final observation from most experiments and pilots is that the savings achieved from real-time feedback instruments merely originate from simple behavioural changes that require little effort or investment of time or money. These behavioural measures focus particularly on the reduction of unnecessary energy consumption (breaking with 'bad' energy consumption behaviour habits such as leaving the lights on in empty rooms) and reducing base load consumption (such as turning the thermostat down earlier in the evening and checking the monitor before going to bed). These quick-win measures require little effort, yet contribute to savings immediately. In most studies, longer-term measures (investments) such as insulation or double glazing on the other hand were rarely mentioned as a result from direct feedback. Longer-term investments such as high-efficiency boilers, double glazing, roof insulation and solid wall or cavity wall insulation are more likely to follow from indirect feedback, as was suggested in the MijnOxxio-experiment.[22] As a result, direct (real-time) feedback and indirect feedback should therefore not be considered as mutually exclusive, Both types can actually complement one another quite well. A real-time display can be the most convenient tool for immediate monitoring and consumption behaviour change at the operational level. Online long view consumption analytics and other indirect feedback tools, such as the bi-monthly energy usage statements, have the potential to become a tactical instrument for interim evaluation and forecasting of annual consumption. Finally the annual bill could become a benchmark for final evaluation of the past consumption year and the determination of a next year's savings goal and/or longer-term investment decisions.

The following section will set out how the main findings in the Netherlands build on the wider international literature already existing on the interventions to change energy behaviour based on smart metering based feedback instruments.

The Dutch smart metering experiments and pilot results in international context

To help contextualise the headline results from the smart metering consumer behaviour experiments and pilots in the Netherlands, an international literature review of similar trials was conducted alongside this monitoring program. A number of leading international review studies exist in which the potential impact of real-time feedback in particular for awareness raising and energy savings is confirmed. In 2010, the American Council for an Energy-Efficient Economy (ACEEE) conducted a comprehensive meta-analysis of 57 (mostly small-scale and

22. The study was unable to properly clarify the extent to which this is the result of the MijnOxxio feedback intervention.

short-term) studies in nine different countries, and found that feedback with smart metering led to an average reduction between 4 % and 12 % in energy consumption, in which case systematically higher savings (9 %) were established in pilots with real-time feedback (Ehrhardt-Martinez et al., 2010). In 2011, another large literature review was released by VaasaETT, by order of the European Smart Metering Industry Group (ESMIG), with a global analysis of more than 100 smart meter pilots, with more than 450,000 households in. The review suggested that smart meters in combination with in-home displays (IHD) were most effective in achieving involvement amongst consumers and most successful in achieving savings, with an average of 8.7 % total (Stromback et al., 2011). Moreover, VaasaETT and ACEEE both demonstrated that the savings were persistent over the measuring periods up to more than a year compared to control groups, and could increase even more through the purchase of more energy-efficient appliances, for example. Other feedback instruments, such as websites and extra informative invoices, showed lower savings (5 to 6 %). In general, the international literature suggests that the more immediate and frequent the feedback, the greater impact on energy consumption (MacLaury et al., 2012).

However, not all international research is applicable to the Dutch situation. Much comes from the USA, Canada and Australia, where extreme climate conditions (and potential problems with regard to security of supply) and different consumption patterns (use of large electric equipment/appliances, such as pool heating, air conditioning, etc.) play an important role. It seems, in general, that countries with the highest peak consumption periods are also observed as the largest outliers in terms of savings achieved.[23] Even research from other Western European countries in the field of smart meters can only be used to a limited extent for the Netherlands. In Scandinavia, for example, nearly all of the energy consumption is based on electricity (especially for heating and saunas), unlike the Netherlands, where a large part of the household energy consumption is related to natural gas.[24] Also research from countries such as Italy, Spain and Portugal is also only comparable to a limited extent, due to the larger number of air conditioning units, which has a major effect on the average reduction in electricity consumption relative to the Netherlands at present.

Surrounding countries such as Belgium, Germany, the United Kingdom and Ireland are more suitable for benchmarking for the Netherlands, due to more similar climatic conditions, consumption patterns, and a dual fuel energy mix based on electricity and natural gas for room heating, cooking and hot water.[25] However, only the United Kingdom and Ireland have conducted scientific research at a national level on the effectiveness of savings achieved with the smart meter, in combination with additional feedback systems and both are briefly presented below.

23. Examples hereof are the pilots conducted in Ontario, Canada in 2006 and 2009 (7 % savings for electricity achieved by frequent users), Eco Pioneer Programme in Victoria, Australia in 2009 (15 % electricity and 18 % gas, multiple intervention part). Also, the smart meter was not used in all of the studies.

24. The electricity consumption in these countries is therefore higher than that in the Netherlands, by an average of 5 times.

25. In England, approximately 85 % of all households use natural gas for heating purposes, on average. In Ireland it is approximately 45 %. Approximately 50 % of households in Germany and Belgium also use natural gas for heating. The Netherlands has the highest percentage of households connected to natural gas, with approximately 98 %.

THE UNITED KINGDOM (UK)

In the UK, the largest consumer study was undertaken in this area in the world to date. The Energy Demand Research Project (EDRP) ran from 2007 to 2010 and considered the effectiveness of savings achieved with the smart meter, in combination with different feedback systems (AECOM, 2011). In this research programme, which comprised multiple trials, including approximately 18,000 households with a smart meter, experiments with smart meters and real-time displays showed consistent and generally persistent savings of around 3 % on average for electricity, compared to households with just a smart meter (Smith, 2011).[26] According to the researchers, the achieved savings seemed mostly the result of simpler (behavioural) changes. This was also observed in the Dutch trials as highlighted in the previous sections of this chapter.

Pilots with web-based services did not show any demonstrable savings in the EDRP. However, this technology is developing rapidly and real-time applications for online use on PC, smart phone and tablet (apps) have since been introduced to the market. Online applications are potentially promising, especially due to the comprehensive graphic analysis and presentation options and in combination with the ease of use associated with modern mobile media. It remains to be seen, however, whether online systems will also live up to these expectations in reality. Darby (2010, 2011) states that *in-home displays with an appealing and intuitive interface at an easy accessible location in the house will be a crucial first step for many consumers to attract active consumer interest and engagement in accessing energy information from the smart meter*. Advanced online systems on PC, tablet and smart phone must then not necessarily be seen as an up-to-date substitute for in-home displays, but rather as a complementary option.

As in the monitoring report for the Parliament in the Netherlands, a similar conclusion was also drawn in the EDRP with regard to the mutual relationship between direct and indirect feedback. This was phrased as follows in the final report (AECOM, 2011):

> The distinction is important because, although there is a general finding that households take a positive view of feedback, it matters how detailed it is and how closely linked to specific actions, in time and in level of disaggregation. Logically, aggregated feedback (e.g. quarterly or annual consumption) is more relevant to one-off changes that have a persistent impact, such as installing insulation or upgrading a heating system. More fine-grain, real-time feedback is more relevant to routine behaviour and purchases of equipment used intermittently (e.g. washing machines, televisions). By extension, aggregated feedback may be more relevant to the fuel used for heating (most often gas) and real-time feedback to electricity.'

IRELAND

A consumer study was conducted in Ireland between 2009 and 2011 to test the impact of the smart meter in combination with different feedback interventions, in the context of the National

26. One trial in the EDRP showed savings to be persistent up to more than a year, other EDRP findings indicated support over time from interventions (e.g. advice or billing information) may be required for savings to be sustained for longer periods.

Smart Metering Programme (NSMP). In the so-called Customer Behaviour Trials (CBT), the responses from a representative group of 7,000 consumers to the introduction of the smart meter in combination with time-of-use pricing and different feedback intervention types such as periodic home energy reports and a real-time electricity display (developed especially for this study), were observed (CER, 2011). The combined offer of smart meters, home energy reports with bi-monthly invoices and real-time displays in this study led to the highest average electricity savings of 3.2 % overall and 11.3 % at peak consumption intervals.[27] The in-home display led to an extra savings of 2.1 % (4.4 % at peak consumption intervals), compared to households that only received the periodic home energy reports (Foster et al., 2012). The combination of home energy reports and displays also provided the highest savings effect for gas, of 3.6 % compared to households with just a smart meter (CER, 2011).

Concluding remarks

Research in the Netherlands points out that the smart meter, in combination with direct feedback, in particular, can significantly change energy-related behaviour in homes resulting in substantial savings. However, whether households with smart meters and direct feedback interventions will be able to actually achieve average savings of 6.4 % for electricity and 5.1 % for gas as mentioned in the national cost-benefit analysis, remains to be seen. The experiments and pilots indicate that initial achieved savings are only likely to be persistent if the feedback medium tailors the user's practical preference and if the functionality and data presentation (interface design) match with the consumer's interests and capability for engagement and reinforcement with the feedback system. Sophisticated online instruments are potentially powerful to help reduce energy demand, but more so for individual use amongst already committed technology minded subsets of the population, looking to further optimize household energy consumption. The extensive data analytics and graphic presentation options in combination with the ease of use associated with mobile media such as laptop, tablet or smart phone, provide the required added value for habit formation with the web tool. Otherwise, less committed and technology minded consumers or less capable consumers prefer the accessibility of a functional simple yet visually and family appealing in-home display. Although not yet investigated as such, it can be hypothesized that especially for older people, those with low levels of education or low levels of numeracy or computer literacy, for example, an in-home display could be a necessary first step to activate consumer interest and engagement in accessing energy information from the smart meter.

However, different forms of feedback are not mutually exclusive, but can actually complement each other. Direct feedback leads to quick-win measures in particular: simple behavioural changes that seem effortless and don't cost much time or money to implement, yet contribute immediately to savings. Examples include switching the lights off in empty rooms, avoiding stand-by use, etc. Longer-term investments such as insulation (weather strips, double glazing, etc.), are generally not considered as a result of direct feedback. Conversely, long-term measures tend to show up more as a result from indirect feedback and the bi-monthly energy usage statements.

The experiences so far in the Netherlands are fairly consistent with the international research literature. Although not all international research is equally suited for comparison to the Dutch situation, the international consensus is still that the smart meter, in combination with accessible real-time feedback, in particular, can provide the most effective stimulus for awareness raising and the development of motivation amongst consumers to monitor and better manage their energy consumption. Compared to the experiences with feedback through in-home displays in the United Kingdom and Ireland (roughly 3 % on average for electricity and gas), the estimated potentials in the cost-benefit analysis for the Dutch consumer (6.4 % for electricity and 5.1 % for gas), due to direct feedback, are rather high. Even so, various pilots indicate that these potentials are realistic, on the condition that the feedback tool meets the practical user preferences and the functionality and data presentation (interface) fit the consumer's interests and capability. In doing so, habit formation and family dynamics with the tool will become more likely, as well as the persistence of the achieved energy savings.

27. For comparison to the Dutch experiences, it should also be taken into consideration that these results were also influenced through the application of variable supply rates for electricity and gas.

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