Impact of Home Energy Monitoring and Management Systems (HEMS)

Triple-A: Stimulating the Adoption of low-carbon technologies by homeowners through increased Awareness and easy Access D2.1.1. Report on impact of HEMS

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D2.1.1. Report on impact of HEMS

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1. Summary

This report answers the question: How can HEMS be used to influence energy-saving behaviour of homeowners? Lessons regarding the feedback from HEMS to influence energy-saving behaviour have been explored and specifications of HEMS to influence energy saving by households are given.

Generally, the implementation of the Triple-A HEMS should appeal to (1) end-users (households) and (2) local authorities. Triple-A partners will provide HEMS to households to encourage them to change their energy behaviour and to trigger interest in the adoption of low carbon technologies. Another goal is to apply HEMS in demonstration exemplars (WP 4) to monitor the energy consumption of households and analyse consumption data before and after applying low carbon technologies.

HEMS with real time feedback have a good potential to influence the energy use and subsequent savings of households. In order to realise a structural change of the energy use behaviour it also must become customary for households to use the feedback system. The need of forming an energy saving habit also sets demands on the functionality and design of the feedback system. It must meet the preferences, capabilities and interest of a heterogonous group of homeowners or should be designed for specific customer segments. Direct feedback instruments primarily influence low-cost-quick-win measures: simple changes in behaviour that require little or no effort or investments. These behavioural changes however can potentially lead to substantial immediate savings.

The rollout of smart meters and HEMS differs strongly between the EU countries and the Triple-A countries. Energy providers can play an important role in the rollout of HEMS. The use of smart meters and HEMS and providing easy access of HEMS to homeowners could be one of the instruments of local energy saving programs and community-based reinforcement strategies of local authorities. A neighbourhood approach aims to enable more positive outcomes for energy savings and uptake of renovation measures, by using peer-to-peer communication, personal advice, trialling in demo houses and demonstration in pop-up centres and on local authority websites.

To monitor actual CO_2 savings by local authorities within the demonstration areas, baseline requirements for HEMS deal with recording (or accessing data related to) annual energy use gas and/or electricity within the properties for a period of 12 months before and after installation. Next to baseline requirements local authorities can choose discretionary functions and requirements of HEMS, including e.g. measuring grid energy monitoring and comfort performance.

HEMS will also be used to give real-time feedback of the energy use to homeowners helping them to manage their energy consumption. For this purpose recommendations are:

- **HEMS should be easy to use and accessible, and fit for purpose.**
- **Feedback should be real-time, frequent feedback enables the user to link behaviour to consequences.**
- **The specifications of the HEMS should match with the household characteristics and the willingness to use HEMS. A distinction between user groups is advisable: some users explicitly have more interest in more functionalities (and thus a more complex HEMS, others want a more intuitive user interface.**
- **Whether adoption of HEMS leads to the adoption of renovation measures is not (yet) known.**
- **HEMS should appeal to certain conditions of the homeowner (segments) or to solving issues within the home.**

Overall recommendations for choosing HEMS include:

- **The HEMS should be cost-effective.**
- **The installation of the HEMS should be easy (preferentially without electricity connection).**
- **The intrusion time for installing in the home should be minimized.**

- **A preference is given for HEMS that local authorities can experiment with free-of-charge to avoid de minimis statements.**
- **HEMS choice by local authorities will be influenced by the need to follow up KPI's for energy saving, and thus by the compatibility with their own energy management system for analysing building stocks.**

2. Introduction

2.1 The role of HEMS in Triple-A

This report is written in the framework of the Interreg 2 Seas project “Triple-A: stimulating the Adoption of low-carbon technologies by homeowners through Awareness and easy Access” (http://www.triple-a-interreg.eu) funded by the European Fund for Regional Development and the Provinces of South Holland and West Flanders. In Work Package 2 of the project, seven Local Authorities (LAs) will monitor the energy behaviour in target areas using demo exemplars. They will also evaluate the effectiveness of the use of home energy monitoring for stimulation pro-energy-saving behaviour.

Home energy monitoring and/or management systems (HEMS) are tools that could be used by homeowners to increase awareness, which might ultimately also lead to adoption of energy-saving measures. If the system only provides **insights** we speak of a **Home Energy Monitoring System**. The use of Home Energy Monitoring Systems is not new and (often) related to the rollout of smart meters in EU-countries as a precondition to give consumers feedback about actual energy consumption to encourage households to lower their consumption. A smart meter is not a necessity though. If the system allows **control**, we identify it as **Home Energy Management System**. The system includes energy consumption and the eventual energy the households themselves produce, use and/or deliver back to the grid via renewable energy sources like PV-panels. Chapter 5 explains in more detail the definition and classification of HEMS.

From the Triple-A perspective we look at how the awareness of HEMS - and easy access provided by local authorities - can be improved to influence energy saving. In the Triple-A project the partners will provide HEMS to households to encourage them to change their energy behaviour and to trigger interest in the adoption of low carbon technologies. Another goal is to use HEMS to monitor the energy consumption of households and analyse consumption data before and after applying low carbon technologies.

2.2 EU policies on smart meters and smart grids

To be able to put the developments and results of HEMS in the separate EU countries and by local authorities in perspective, attention should be paid to EU policies in this policy area.

According to the EU directive 2012/27/EU on energy efficiency (EU, 2012) at least 80% of EU-households should be equipped with smart meters by the end of 2020. A smart meter is defined in this directive as an electronic meter that measures energy consumption and can transmit these data using a form of electronic communication to give feedback about actual residential energy consumption and costs with the intention to encourage households to lower their energy use.

In the framework of the implementation of the EU Clean Energy Package (EC, 2016) homeowners are expected to become active energy users and prosumers, meaning active in the use and gaining of cleaner, more sustainable energy sources. Local authorities will play a role to facilitate this activation in collaboration with supply side actors such as network operators and energy service companies. A first step to achieve this goal is that homeowners become more aware of their own energy use and production.

The end of 2016/beginning of 2017, the European Commission published a proposal stating that all consumers should be entitled to request a smart meter from their supplier (European Commission, 2017). Smart meters should allow consumers to reap the benefits of the progressive digitalisation of the energy market via several different functions. Consumers should also be able to access dynamic electricity price contracts.

The rollout of the smart meters is inextricably linked and dependent to the rollout of smart grids[1]. Via smart grids the energy flows can be monitored and adjustments can be made dependent on the

[1] The Smart Grids Task Force was set up by the European Commission in 2009 to advise on issues related to smart grid deployment and development (source: https://ec.europa.eu/energy/en/topics/markets-and-consumers/smart-grids-and-meters/smart-grids-task-force).

changes in energy supply and demand. When smart meters are related with smart grids consumers and suppliers can get information about both their real-time and predicted energy consumption as well as their possible energy production. Consumers can adapt their energy usage to different energy prices throughout the day or night, lowering their energy use in certain hours and thus saving money. On the other hand the system offers consumers who produce their own energy from sustainable sources, the possibility to react at prices and sell excess to the grid. On the basis of the production figures (and other information like weather forecasts) suppliers can for instance better plan the integration of renewable energy into the grid. According to the EU this smart metering and smart grids rollout can reduce emissions in the EU by up to 9% and annual household energy consumption by similar amounts (European Commission, 2018, website).

2.3 Research questions

In this report the following research question will be answered: ***How can HEMS be used to influence energy-saving behaviour of homeowners?***

The research question will be answered by finding answers on the following sub questions:

- What are lessons learned regarding the feedback from HEMS to influence energy-saving behaviour?
    - What behavioural characteristics of homeowners support the adoption and continued use of HEMS?
    - What are the roles of local authorities, in cooperation with energy service companies and energy network operators in offering HEMS?
- What should be the specifications of HEMS to influence energy saving by households?
    - What should be the specifications of HEMS to monitor and analyse energy consumption data of households?
    - What could be specifications of HEMS to stimulate adoption of energy-saving measures?

The research methodologies used are twofold. Via an extensive literature review the experiences with existing HEMS are analysed and evaluated. Besides that the (first) experiences (and expectations) of Triple-A partners with HEMS are inventoried.

2.4 Structure of this report

Chapter 2 deals with the question what the best way is to give feedback to consumers and what effects that could have on the energy consumption of households. Chapter 3 explores consumer segments in relation to the willingness to use HEMS. Chapter 4 provides insight in the use of HEMS in the Triple-A partner countries and the role of government policies, energy service companies and network operators. The needed specifications of HEMS for local authorities are analysed and described in chapter 5.

3. HEMS and feedback on energy consumption

3.1 Introduction

We explore if HEMS can influence homeowners in such way that they adapt their energy using behaviour. In this research we assume the way feedback is given is an essential characteristic of HEMS to allow activation of homeowners. Households can get feedback on their energy consumption in various ways:

- Indirect feedback: afterwards, in retrospect and on paper (e.g. using energy bill).
- Direct feedback: immediate, in real time and computerised (e.g. using HEMS).

Traditionally the only way feedback was given to owners was via the monthly energy bill and the annual overview of their energy use provided by the energy service company (energy providers). The last decades this situation has changed considerably and direct feedback can be given by smart meters and HEMS; devices that give computerised real-time (visual) feedback on gas and/or electricity consumption (Van Dam et al.; 2010; Kobus, 2016).

This chapter describes and analyses (on the basis of a study of HEMS that are already operational) the demands HEMS must meet in order to be able to provide adequate feedback to the users. The chapter also addresses the question what (an adequate) feedback can generate in terms of the energy saving potential of HEMS.

3.2 Successful feedback and behavioural change

We assume that in order to be able to change their behaviour consumers or homeowners need to get adequate feedback and explore this assumption with literature research. We expect that this feedback should enable them to determine their energy consumption pattern. We also explore how HEMS can provide them knowledge about the possibilities to change their behaviour and get insight in the possible profits that could be realised if they change that behaviour.

Research by the European Environment Agency (2013) indicates that **combining direct and indirect feedback** from energy providers has been (so far) the most successful in changing consumer behaviour and achieve energy savings. Direct feedback could include information received via the consumer's computer, or via smart meters combined with in-home displays. Indirect feedback could include more informative and frequent bills containing historical and/or comparative information on energy consumption. A limitation of this EEA report is that it was more focused on the instruments themselves than on the behaviour and consumption practice that needs to be affected.

In order to make optimal use of the energy saving potential it is important to understand the relationships between feedback measures, demand response measures and energy efficiency programs. Research finds that following interaction from feedback measures, **setting individual energy-saving targets by the consumers themselves** have the potential to yield the best results. Research by Murray et al. (2015) also indicates that households and the individual appliances they use have distinct energy consumption patterns, and thus a **personalised feedback** approach is needed.

We analyse what common requirements HEMS should meet in order to be able to give adequate and useful feedback to homeowners. In this respect it is also important to consider the need that feedback and resulting energy savings can be used on a more general level by local authorities and other stakeholders to adapt and/or sharpen their energy efficiency policies and programs.

There is a body of literature about successful feedback to households in respect to energy consumption. According to Fischer cited in Kobus (2016) and Darby (2010) the following ingredients or characteristics are essential for giving adequate information and feedback:

- There must be **multiple options** in the user interface to choose from.

- The HEMS should contain (an) **interactive element(s)**.
- The **feedback frequency** should be (far) more often than monthly: e.g. continuously, via daily load curves or immediately after the action of switching on and off.
- Information should be detailed and should show appliance-specific breakdown of usage.

  Kobus' (2016) preference studies show that people demonstrate a preference towards appliance-specific breakdown, but: "people want those breakdowns, but at the same time, the breakdowns make the feedback too complex".

- It must be possible to **make comparisons** with previous periods.

  Kobus (2016) remarks that is valuable to provide comparisons with previous periods (historical data) and it is also preferably to give insight in normative comparisons with same households living in the same type of dwelling in the neighbourhood.

Kobus (2016) did a study among households using smart plugs (set of nine plugs and a web portal, and a link with a smart meter) and smart thermostats (display replacing the thermostat in the living room, connected to the smart meter) that use frequency serves as the underlying mechanism for the success of an EMS (she refers to Energy Management Systems instead of HEMS). Kobus states that real-time feedback given by an EMS can only be effective over time if households remain using it frequently. The EMS should therefore easy to use and accessible.

Kobus (2016) thus adds other key elements for successful feedback to the above series:

- Feedback should be provided **real time**.
  - Frequent feedback is necessary because it enables the user to link their behaviour to the consequences.
- Expressing **energy consumption in costs** is preferred (Karjalainen cited in Kobus, 2016).
- HEMS should be **accessible and attractive** to use **for all household members**. They all consume energy and every household member is able to influence the household energy use.
  - Ideally feedback information should become part of the daily life of the occupants and also should become a subject that is daily discussed by the household members.
  - As many people have difficulties in dealing with numbers and are unfamiliar with scientific terms, the information should be provided as accessible, readable and comprehendible as possible.
  - Accordingly the design of the HEMS should be simple and to the improvement of accessibility can be assisted by its place and medium.
  - The system and its feedback appear to be most effective if combined with goal-setting and by accompanying the feedback by smiling or frowning faces (McCalley and Midden cited in Kobus, 2016).
  - According to Vringer and Dassen (2016) in-home displays provide the most effective and direct feedback.

Obviously, most HEMS that are currently on the market are not yet offering the needed specifications for successful feedback that are listed above. Chapter 5 elaborates further on specifications for HEMS. In the next section we will assess evidence of energy saving by introducing HEMS.

3.3 Energy savings by feedback on energy consumption

On the basis of academic literature and data available in 2013 the European Environment Agency (2013) summarised the potential for energy savings due to measures targeting behaviour as shown in the Table 1 below.

TABLE 1: POTENTIAL ENERGY SAVINGS DUE TO MEASURES TARGETING BEHAVIOUR ACCORDING TO THE EUROPEAN ENVIRONMENT AGENCY.

Intervention	Range of energy savings
Direct feedback (including smart meters)	5–15 %
Indirect feedback (e.g. enhanced billing)	2–10 %
Feedback and target setting	5–15 %
Energy audits	5–20 %
Community-based initiatives	5–20 %
Combination interventions (of more than one)	5–20 %

Source: European Environment Agency, 2013.

Roughly it is estimated that the effects of direct and/or indirect feedback (whether provided through smart meters, HEMS or via other means) on the energy saving potential could be considerable (varying between 2 and 20%). As stated in the introduction the European Commission expected (in 2012) that the introduction of smart metering and smart grids could reduce emissions in the EU by up to 9% and annual household energy consumption by similar amounts. So the European Commission opts for energy saving potentials that can be situated in the middle or the EEA ranges of possible reductions.

3.3.1 Evidence from studies in the Netherlands

In the Netherlands the expectations were less pronounced. The Dutch Parliament decided in 2011 to introduce standardised smart meters. The Dutch smart meter applies to both electricity and gas. When installing a new electricity meter, the gas meter is also replaced and connected to the new electricity meter (in a wired or wireless fashion; Van Elburg, 2015).

In the Dutch cost benefit analysis of smart meters in 2010, it was estimated that the smart meter in combination with indirect feedback through bi-monthly energy usage and cost statements, to be delivered by energy providers (via a 'home energy report') would result in an average reduction in household energy consumption of 3.2% for electricity and 3.7% for gas. Smart meters combined with real-time and sophisticated feedback should result in an average reduction of 6.4% for electricity and 5.1% for gas (Van Gerwen et al., 2010; Van Elburg, 2014). Research on the actual effectiveness of savings achieved with smart meters in combination with bi-monthly energy reports, pointed out that after a full consumption year households saved, compared to a control group without a smart meter, 0.9% less gas and 0.6% less electricity. One of the reasons was that the energy service companies did not deliver the Home Energy Report to consumers to the best possible extent (Van Elburg, 2014). "The measures reported to reduce energy consumption based on Home Energy Report are not only behavioural changes, such as switching the lights off when nobody is in the room, bus also involve longer-term measures, such as putting up weather strips, replacing light bulbs with energy-saving bulbs and replacing appliances with models that have a higher energy efficiency rating. It is expected that these changes lead to average energy savings of 3.5%." (Van Elburg, 2014).

Before 2011/2012 other Dutch studies have been carried out to determine the effect of experiments with smart meters (and their feedback) on the consumers. However these research projects did not compare the behaviour of households with a smart meter with those without a smart meter. The projects focussed on the influence of the way feedback was given to households with a smart meter. Besides that the experiments were not held with the current range of feedback methods and instruments. Furthermore the homeowners involved generally had higher incomes and higher education levels and were more interested in energy savings than the average homeowners. On the other hand these studies provide also insight in the best ways feedback can be given to homeowners. The studies, described by Van Elburg (2015) are summarised below.

2008: Energy supplier Oxxio commissioned research into the energy saving effects of a smart meter combined with non-real time (or indirect) feedback via an online self-service platform. Oxxio provided customers through a personal web page on their own PC or laptop with additional information both about their (historical) energy consumption as on tariffs and costs. For a period of two years a little more than 2,500 Oxxio's customers were followed (Jonkers et al., 2011). It appeared that customers with a smart meter who used the web application, consumed on average

1,5% less electricity and 1,8% less gas than customers with a smart that where not using the web application. 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.

2009: Energy supplier Nuon commissioned (a small scale) test research into consumer behaviour of consumers with a smart meter and a real-time in-home energy display. The research was carried out in 40 selected households with a smart meter (UC-Partners et al., 2009). Half of these households received a real-time energy display and the other half did not (UC-Partners et al., 2009). The 40 households were comparable with respect to composition, domestic environment and environmental motivation and got the same instructions and recommendations to save energy. After four months it appeared that in the in-home-display-group respectively 81% and 100% realised savings for electricity and gas. In the group without a display the comparable percentages were 47% (electricity) and 65% (gas). The display group also saved considerably more energy (average of 9% for electricity and 14% for gas) than the other group (3% for electricity and 2% for gas, respectively). The display group expressed more positive feelings about the test, complained less about the (time) effort, understood 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. It was concluded that a real-time display can contribute significantly to the willingness of consumers to reduce energy consumption.

2010: the aforementioned NUON research was continued on a larger scale with around 400 households with a display and some 3.000 households as a control group (Noort and Van Ossenbrugge, 2011). Again in the display group energy awareness and development of energy-saving behaviour was increased. This resulted in a reduction in an energy consumption of 4.5% for electricity and 4.6% for gas, that was not observed in the control group. These savings were predominantly realised by 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 by the display group. The fact that the majority of the display group lived in well insulated dwellings (with wall insulation and double glazing) probably had influence on this observation (Van Elburg, 2015).

2008-2012: research by Van Dam (2010 and 2013) on the effectiveness of in-home displays highlighted the relevance of routine use with the feedback system to realise structural savings in the longer term (Van Dam, 2013). In 54 households that had a traditional meter a real-time electricity monitor was installed that provided information on actual and daily consumption and a comparison with a savings target. 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. Within the group that returned the display, the previous savings of 3.9% dropped to a negative savings of -1.0%. Within the display group the savings also decreased, but that depended the frequency households used the display. The energy saving of irregular users (12 households) decreased from 6.3% (after the first four months) to 1.7% (after 15 months). The energy saving of the daily users also experienced a decree, however still realised a reduction of 7.8% after 15 months. Van Dam concluded that the realisation of energy saving depends on the persistence and intensity of the use of the feedback device. Another conclusion was that an energy display is only effective in the long term when it is used by consumers who are receptive to energy savings. Furthermore the importance of family dynamics were emphasised (Van Dam, 2010 and 2013). The study found out that a display installed at a convenient and for all households accessible location triggers family discussions and leads to an increased chance of acceptance and daily use of the display.

As stated above the previous studies and pilots were aimed at a certain group of well-to–do and environmental conscious homeowners and at a certain type of feedback systems. To complement the picture and add supplementary insights two pilots were carried out during the first phase (or the small scale) rollout in the Netherlands that were aimed at fuel poor consumers and feedback systems based on modern media applications. Again Van Elburg (2015) proofs to be an important source of information (Van Elburg, 2015).

Summer 2012-2013: Grid operator Liander carried out a 12-month consumer behaviour pilot, using a smart meter and a feedback app (named ‘Energy Warriors”) for smart phones. The feedback app gave information on energy use in energy-units and costs (electricity and gas) and enabled consumers to compare their energy use with their past use and the use of reference households. The consumers could set a savings target in the app as a stimulus to lower their energy use. Although the feedback system was different than in previous pilots discussed above, the target group still remained more or less the same (homeowners with an above than average income, educational level and environmental consciousness). The pilot (circa 330 households) showed an average reduction in consumption of 3% for electricity and 4% for gas over a year, compared to the forecast consumption for this group (Liander, 2014). An additional consumer experience survey (under approximately 160 participants) showed that although the app had a high effect on raising awareness it hardly changed the energy saving behaviour: 18% of the participants related the measures they took with the app, 35% did not see any connection and 47% only saw a partial connection. This outcome could (partly) be explained by the fact that the pilot group was already environmental conscious and probably had already taken energy saving measures (Van Elburg, 2015).The measures that were taken had a 'low-cost-quick-win' character (this is comparable with the results of the pilots described above). During the pilot period the user frequency of the app spiralled down. At the end around two-thirds of the owners used the feedback app only once a month or even less frequently.

2013-2014: Network operator Stedin (together with housing association Woonbron and the City of Rotterdam) held a nine month trial to map the consumer responses to a smart meter combined with a real-time energy dashboard (the so called 'PowerPlayer'). The in-home energy monitor resembled a car dashboard. Users could see their energy use and the changes in it at a glance, both in real time and for past periods. The information could be compared with the energy savings target they had set themselves and/or previous consumption periods. Contrary to the previous pilots this trial was aimed at circa 140 households in the low rental segment. This group was targeted to gain more insight in the best way to support the fuel poor during the smart meter rollout. The participants realised substantial energy savings, with an average reduction of 5,6% for electricity and 6,9% for gas (Stedin, 2014). Remarkably, more than half of the households achieved savings of more than 10% on both electricity and gas. Approximately half of the households developed a daily or weekly habit to use the energy dashboard and that continued after the nine months trial. Consumer research at both the start as end of the trial showed a high recognition for the dashboard. It was concluded that three-quarters of the households experienced the display as: "a missing link to activate consumer interest and engagement in in accessing energy information from smart metering" (Stedin, 2014). The respondents highly appreciated the energy dashboard because the information was easy to comprehend; the system was easy to operate and delivered only the necessary information. As with the other pilots the measures taken had a 'low-cost-quick-win' character (e.g. turning the heat off and switching lights off) and longer-term measures were not or hardly taken into consideration. Considering the fact that the target group consisted of tenants the latter is understandable.

3.3.2 Evidence from studies in the UK

In the UK the major relevant project was the Energy Demand Research Project (EDRP) that ran from 2007 to 2010. This project – that was commissioned by Ofgem on behalf of DECC analysed the effectiveness of savings achieved with feedback systems, including the smart meter (AECOM, 2011)[2]. The main goal of EDRP was to test the responses of consumers to different forms of information about their energy use. Four energy suppliers each conducted trials of the impacts of various interventions (individually or in combination) between 2007 and 2010. The interventions used were primarily directed at reducing domestic energy consumption, with a minority focused on shifting energy use from periods of peak demand.

The energy suppliers each divided their trials into a number of trial groups to test the impact of different interventions. The following interventions were taken into account in the project:

- Energy efficiency advice.
- Historic energy consumption information (e.g. comparison of current energy use with previous periods).
- Benchmarking of the households' consumption against the consumption of comparable households.
- Customer engagement using targets (commitment to reduce consumption).
- Smart electricity and gas meters.

[2] Ofgem stands for the Office of Gas and Electricity Markets (a non-ministerial government department and an independent National Regulatory Authority). DECC is the Department of Energy & Climate Change (that became part of Department for Business, Energy & Industrial Strategy in the summer of 2016).

- Real-time display (RTD) devices that show energy use (including audible usage reduction alarms).
- Control of heating and hot water integrated with real-time displays.
- Financial incentives (including variable tariffs) to either reduce energy use or shift demand from periods of peak demand.
- Other digital media for delivering information (web, TV).

The interventions were assessed either individually or in combination with each other. Totally the project involved over 60,000 households, including 18,000 households with smart meters. Measures were generally applied at household level but one energy supplier also tested the effects of the measures at community level.

The main conclusions were that with two exceptions, no significant reduction in energy consumption could be determined with interventions that did not include a smart meter. The exceptions identified by AECOM were those either using clip-on real-time displays of electricity consumption or ‘benchmarking’ the individual household consumption against consumption in comparable households. In these two cases it was only one of the energy suppliers that found a significant reduction (in electricity consumption only, not gas consumption), and the effect was small (around 1% savings). The other trials found no statistically significant effect of real-time displays, energy efficiency advice (on paper or online), historic feedback (on paper or online), self-reading of meters or financial incentives to save energy in the absence of smart meters.

In contrast, interventions using smart meters were successful more frequently and with larger percentage savings in energy consumption. According to AECOM this could possibly partly be related to aspects receiving the smart meter (e.g. interaction with the installer or the positive image of getting a new technology). It could also be explained by the different options that were available for a household after a smart meter was installed (e.g. more sophisticated real-time displays fitted by and more frequent and accurate historic feedback and billing).

The results showed that the combination of smart meters and real-time displays consistently resulted in energy savings of around 3% but with some higher and lower savings, depending on fuel, customer group and period. It appeared that the provision of real-time displays were the more important factor in the case of electricity consumption. Savings were generally 2-4% higher than with a smart meter only (with a full range of 0-11% for some periods and customer groups) and these effects were persistent to the end of the trial. In the case of gas consumption, the smart meter itself (e.g. the information provided on consumption and cost) or some aspect of the experience of getting a smart meter appears to be a positive mechanism, resulting in savings of around 3%. According to the researchers, the achieved savings seemed mostly the result of simple (behavioural) changes (Van Elburg 2015).

3.3.3 Evidence from meta-analyses of international studies

In 2010, the American Council for an Energy-Efficient Economy (ACEEE) carried out a meta-analysis of 57 studies in nine different countries on the effect of feedback initiatives on the energy use of households. It has to be stressed that the studies incorporated in the meta-analyses included exclusively the electricity use of households. The results are summarised in figure 1 (Ehrhardt-Martinez et al., 2010).

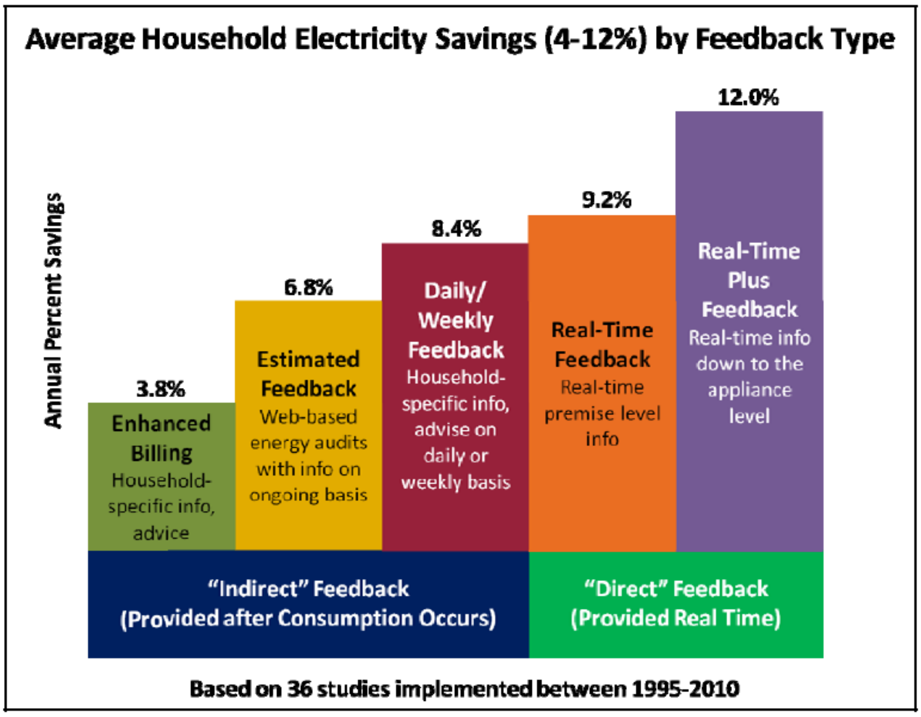

Figure 1: ACEEE: Average household electricity savings by feedback type based on 36 studies carried out between 1995-2010 in countries all over the world.
Source: (Ehrhardt-Martinez et al., 2010).

As presented in figure 1 ACEEE found that feedback with smart metering led to an average reduction between 3,8% and 12,0% in electricity consumption. Initiatives or pilots where real-time feedback was given appeared to have the largest effect on the energy savings, while enhanced billing feedback lead to systematically lower savings

In 2015 another large literature review was published by Ea Energy Analyses in Denmark. They reviewed a total of 39 literature sources, including 24 papers, which describe conducted field studies, and 15 review and other papers (Zvingilaite and Togeby, 2015). The results are summarized in table 2. The reviewed reports and articles include either a detailed description of a particular study on energy consumption feedback, a review of conducted studies or other related discussions. Table 2 includes an overview of the review results by energy and feedback type and the band width of the reported energy savings. In order to eliminate the peaks and lows in the data the authors presented the results also as median values. On the basis of a set of criteria the design quality of the studies were classified and were awarded points for a good study design[3]. Studies which received score 3 according to the criteria obtained the classification 'best'.

[3] The following criteria were used to grade the studies from 1-3: Duration of feedback study (minimal one year's duration), sample size (minimum 100 participants, with some exceptions if the results are significant), test design (with a control group and with before and after data), method for accounting for socioeconomic factors and participants' self-selection and the significance of the results (checked for the best studies). Best studies are the studies with the best design and were awarded with a '3'

TABLE 2: OVERALL ENERGY SAVING RESULTS OF THE STUDIES ANALYSED BY EA ENERGY ANALYSES

	Electricity	Electric heating	Gas/District Heating
Direct feedback			
No. of studies, all/best	14/5	5/1	9/4
Savings, all	0-18%	1-17%	0-8%
Savings, best	1-7%	2%	1-8%
Savings, median, all	3%	3%	2%
Savings, median, best	5%	2%	2%
Indirect feedback			
No. of studies, all/best	25/9	11/4	15/6
Savings, all	-2-10%	0,4-13%	0-14%
Savings, best	-2-5%	3-10%	1-7%13
Savings, median, all	3%	4,5%	3%
Savings, median, best	2%	4%	4%
All			
No. of studies, all/best	39/14	16/5	24/10
Savings, all	-2-18%	0,4-17%	0-14%
Savings, best	-2-7%	2-10%	1-8%
Savings, median, all	3%	4%	3%
Savings, median, best	2%	3%	3%

Source: Zvingilaite and Togeby, 2015.

Savings, as a result of feedback on electricity consumption seem to fall within a broad interval of -2% (where consumption has increased) and 7%. Nonetheless, when looking at the median of the best studies, the resulting savings are 2% for indirect feedback and 5% for direct feedback. Thus, providing (direct) feedback on household electricity consumption seems to have a positive effect on savings. The results of the best studies show that feedback on electricity consumption in households with electric heating leads to savings of 2% and 4% for direct and indirect feedback respectively. In the case of electric heating indirect feedback appears to have more effect on savings than direct feedback. That is also the case with respect to gas or district heating. Overall savings potential from the feedback on gas and district heating consumption seems to be 3% for both, all and best results. However the best results show savings of 2% for direct and 4% for indirect feedback. According to the authors the comment has to be made that the best results of indirect feedback studies are dominated by the results for fuel poor consumers and therefore might be affected by this bias. Another general comment that is made by the authors is that studies that show high savings are not among the best and usually have small sample and/or a short duration as well as include goal-setting or a more de-tailed representation of end-uses.

Also in 2015 another major evaluation of meta-studies on energy savings through feedback was carried out by the European Commission’s Joint Research Centre (JRC). This study – done on behalf of DG ENER – aimed to better understand the potential of different energy feedback systems and to determine how these could contribute to achieve energy savings in a consistent and more structural way (Serrenho et al., 2015). The JRC report makes reference to (amongst others) the reports mentioned earlier in this section (e.g. Zvingilaite and Togeby, 2015) and collected a dataset of 118 feedback applications that include the following categories:

- 3 consumption types (electricity only, electricity and heating, heating only).
- 16 different countries (mainly in North America and North Europe).
- 2 feedback types (direct and indirect).
- 6 media types (bill, card, In-House-Display (IHD), mail, PC or web, mixed mode).
- A large range of sample sizes (from about 10 to almost 100,000 households).
- Different duration periods (from 2 weeks to 3 years).

The JRC report presents a crystal clear breakdown analyses of the studies and presents interesting analyses/figures about the energy savings per:

- Consumption type and geographical area of the studies.
- Consumption and feedback type.
- Consumption type and the period of the study.

- Feedback type and medium used.
- Feedback type and frequency of interaction.
- Feedback type and duration of the study.

The meta-analyses of the 118 studies shows further that feedback can reduce the households' energy consumption up to a realistic 5% to 10%. According to the study feedback is the most effective when it is:

- **Associated with a well-defined and challenging goal**.
- **Accompanied by advice** for reducing energy consumptions.
- Tailored to the householder.
- Presented clearly and engagingly.
- Delivered regularly and with high frequency.
- Made through enhanced billing versus standard billing.
- In the presence of in-home devices, web based, interactive and digital.
- **Capable of providing information by appliance** (even if cases are still rare);

At the same it is concluded that there still are many uncertainties in the studies and there has been little comprehensive knowledge gathered about the effectiveness and cost benefit of feedback. What are for instance the effects of feedback on consumers in different social and demographic groups or on appliance purchasing decisions? Has feedback a structural impact on the behaviour of households or does it has to be renewed or reshaped over and over again? Is it possible and suitable to use feedback to facilitate the sharing of energy information between households, friends or neighbours? Besides that the current studies have divergent outcomes with respect to the cost-benefit outcomes for feedback with an advanced metering infrastructure. According to the JRC report this also needs to be studied further as well as the conditions under which the costs of feedback outweigh the benefits.

The report also evaluated the contents and state of the art of the National Energy Efficiency Action Plans (NEEAPs) of the EU Member States. Within the framework of the evaluation of the National Energy Efficiency Action Plans of the Member States the study establishes that there is still a long way to go with respect to the rollout of smart meters. Despite the fact that almost all EU Member States have set requirements on individual consumers' measurements and a majority of them have introduced minimum requirements for billing, an extensive rollout of smart meters is not yet a reality.

3.4 Conclusions feedback and energy savings

With respect to the observations and conclusions below one has to realise that:

- The results sometimes are based on small scale pilots with the involvement of energy saving conscious and relatively affluent homeowners. Nonetheless the results of the meta-analyses of a range of studies that are included in this chapter probably give a more representative impression of the feedback results to average energy consumers.
- There are vast differences in scope of the studies. Some studies are focussed on consumers in general and others on groups of homeowners. Most studies only take effects of feedback on the energy savings on electricity into account and only a few also make distinction to the saving effects of the gas end or district heating consumption.
- Many studies date from around 5 years back and sometimes sketch disappointing results with feedback of web based tools. Technological developments go fast. The real-time applications and (potential) possibilities of current graphics and presentation modes on PC's, apps and tablets are incomparable with those of only a few years back.
- There are large gaps in knowledge about the precise and structural effects of feedback and the differences of the effects on different socioeconomic groups of homeowners (or consumers).

Nonetheless some general observations and conclusions can be made:

- The studies show quite some variation in the effects of feedback on the energy consumption behaviour of consumers. The resulting energy saving percentages are quite diverse. Although there are some outliers, the average energy saving percentage seems to fluctuate between 2% to 4%.
- There appears to be general agreement about the fact that **direct feedback** to households has more positive effects on the energy consumption than indirect feedback. However, there are indications that the effects vary between consumption types. For instance the meta-analyses carried out by Zvingilaite and Togeby (2015) indicate that direct feedback yields the best results on the electricity consumption of households. While indirect feedback appears to have more positive effects on savings in the cases of electric heating and gas district or gas heating.
- Most studies show however that **smart meters with real time feedback** have a good potential to influence the energy use and subsequent savings of households.
- In order to realise a structural change of the energy use behaviour it also must become customary for households to use the feedback system. Some studies point out that it is important in this respect to **stimulate the communication and interaction within households**.
- The need of forming an energy saving habit also sets demands on the **functionality and design** of the feedback system. It must meet the preferences, capabilities and interest of a heterogonous group of homeowners or should be designed for specific customer segments. The results so far indicate that applications on PC's, tablets or smart phones are particularly suited for owners that are already committed to energy saving and are technology experienced and oriented. This group is not easily deterred by elaborate data and graphics. Although as stated before the developments in this area go fast, it could still be necessary to develop more functional, more simple and more visual attractive displays for those households and owners who do not have such a feel for technology or energy saving or do not have the means to make the effort.
- A general conclusion is that (direct) feedback instruments primarily influence low-cost-quick-win measures: simple changes in behaviour that require little or no effort or investments. These behavioural changes however can potentially lead to substantial immediate savings. Some studies suggest that the execution of energy saving measures (e.g. installing of insulation or replacing of installation) that require longer term investments are more likely to follow from indirect feedback like personal energy advice. This upholds the need to pay attention to both direct as indirect feedback systems.
- Clearly, energy savings by HEMS vary strongly. If HEMS are being implemented without taking other (physical) energy saving measures the energy saving effects disappear after some time. The described studies did not take into account **community-based reinforcement strategies** - or the uptake of larger renovation measures -, which will be trialled in Triple-A.

4. Users of HEMS

4.1 Willingness to use HEMS

Van Elburg (2014) argues that sophisticated real-time web services on PC, tablet and smartphone are potentially powerful to help reduce energy demand, but more so with already committed and technology minded subsets of the population. Less committed and/or less technology minded consumers or less capable consumers prefer the accessibility of a simple yet visually appealing in-home display.

Darby (2010) explored the use of smart meters and HEMS extensively, especially applied in the UK. She is using the word AMI technologies, in which AMI stands for advanced metering infrastructure. Darby recognises that not all people are able or willing to use HEMS: "The stories of those who are not interested in their displays, or who cannot put them to use for energy management, add an important dimension to the unfolding story of smart metering. They highlight the need for simple, clear customer interfaces, but also for an approach that recognises the limitations of AMI technologies."(Darby, 2010). Darby concludes to be aware of:

- Customers that do not care about their consumption;
- Customers who feel that they already have reached the limit of what they can do to reduce their energy consumption;
- Customers living in dwellings that make it difficult and expensive to reduce their energy consumption.

For those homeowners who regard HEMS as something new for the house, it is relevant to highlight the importance of innovation adoption characteristics, as for example introduced by Rogers (2003). From innovation theory we can expect that the higher the relative advantage – e.g. a financial incentive or saving -, the more willing the homeowner will be to use the HEMS. The lower the complexity of the HEMS, the more likely it is that it will be used. Also A HEMS that is not compatible with the homeowners lifestyle or building services will reduce willingness to adopt. If a HEMS can be tested in advance, it will be more likely that the homeowner continues its use. If the HEMS is more visible – for example at neighbour houses – the chances increase that the homeowner will adopt a HEMS.

It is expected that dynamic energy pricing will stimulate the active control over appliances, e.g. willingness of customers to use HEMS and e.g. temporarily reduce the set-point temperature of heating and to postpone the start time of an appliance given that this would obtain some financial benefits.

4.2 Promising user groups HEMS

Volmer (2018) carried out a survey about perspectives on the use of HEMS among homeowners in the municipality of Rotterdam. The research question is: How can homeowners be classified based upon perceptions, attitudes and behaviour with respect to the use of HEMS?

The research methods used were a literature review and the Q-method.[4] A survey using the Q-method was conducted among 39 owners of single-family homes in various Rotterdam neighbourhoods. In order to find shared views among respondents, a principal component analysis (PCA) was performed.

Five different types of homeowner can be distinguished: the optimists, the privacy-conscious, the technicians, the sceptics, and the indifferent. Their opinions vary as regards the added value of a HEMS, what characteristics a HEMS should have, how much confidence they have in the energy-saving effect of such systems, and their views on the privacy and safety of HEMS.

[4] The basic idea behind the Q-method is that a view has to be understood from within the individual subject. This is done by having the subject (the homeowner) react to various propositions relating to the topic and then looking at the positions (i.e. reactions to propositions) adopted by the subject.

The optimists group is characterised by confidence in the possibilities offered by a HEMS. They expect a HEMS to offer them useful advice and functions as well as delivering energy savings, and they are not afraid of possible risks.

The privacy-conscious are characterised by their lack of trust in HEMS security. They worry about the privacy of their data if they were to use a HEMS. At the same time, they are convinced that a HEMS could help them in a number of areas to reduce energy consumption.

The technicians are technically inclined and find a HEMS attractive as a gadget. They want to have access to a HEMS in a variety of ways and dismiss as ridiculous the idea that a HEMS can be the source of dangerous radiation.

The sceptics would prefer to stay in control and expect the learning capacity of a HEMS to be fairly quickly exhausted. They do think that a HEMS can lead to lower energy consumption, but still have a relatively large number of objections that stand in the way of them enjoying its use. They are also less interested, relatively speaking, in their energy consumption.

The indifferent find a HEMS basically too technical. If they purchased a HEMS, it would above all have to be simple and positioned in a fixed location, and they would mainly find it useful because of the overviews provided by a HEMS.

Factors that emerge among the homeowners who appear to be open to the idea of using a HEMS are energy awareness, confidence in the effect of the HEMS, appreciation of the advice provided by a HEMS and, above all, no worries about possible drawbacks such as security and radiation risks or conflicts with other members of the household. The factors that make homeowners less keen to use a HEMS are high purchase costs, a lack of technical affinity and concerns about security and privacy.

The target group classification offers first of all a basis of shared views among homeowners which must be taken into account. The target group classification can be used as input for a way in which a local authority can offer HEMS that is in line with the wishes of the homeowner.

Additionally innovation theory (Rogers, 2003) highlights the importance of mingling innovators and opinion leaders with regular homeowners, and the need for (local authorities organizing) peer-to-peer communication between homeowners to reach early adoption.
The study by Volmer (2018) especially addresses customer segmentation of HEMS. Decisions regarding the adoption of energy saving measures are made in the context of everyday life in the home, how space is used, how activities create identity and how conflicts and aspirations between household members can be solved and arranged (Wilson et al., 2018).

5. The rollout of smart meters and HEMS

5.1 Introduction

In this chapter first we describe the rollout of smart meters in Europe and the Triple-A partner countries. As mentioned before the rollout of smart meters is almost a prerequisite for the rollout of HEMS, but not a necessity. Second we focus on the diffusion of HEMS in those countries and specify the role of energy suppliers, network operators and e.g. independent market actors like customer organisations. In the last part the various roles of Local Authorities in using smart meters and HEMS, and providing (easy access to) HEMS to homeowners are specified.

5.2 Rollout of smart meters in Europe

It is expected that in 2020 some 80% of the households in the EU will be equipped with a smart meter (Vringer and Dassen, 2016).

On 30 November 2016, the Commission published a proposal stating that all consumers should be entitled to request a smart meter from their energy supplier. Smart meters should allow consumers to reap the benefits of the progressive digitalisation of the energy market via several different functions. Consumers should also be able to access dynamic electricity price contracts. The EU-countries are free to choose the technologies and functionalities and e.g. if the smart meters are connected to an in-home display (IHD). In Sweden and Italy all households are already equipped with smart meters. To measure cost effectiveness, EU countries conducted cost-benefit analyses based on guidelines provided by the European Commission. A similar assessment was carried out on smart meters for gas.

A 2014 Commission report (European Commission, 2014) projected that:

- Close to 200 million smart meters for electricity and 45 million for gas will be rolled out in the EU by 2020. This represents a potential investment of €45 billion.
- By 2020, it is expected that almost 72% of European consumers will have a smart meter for electricity. About 40% will have one for gas.
- The average costs of installing a smart meter in EU Member States varies between €200 and €250.
- Smart meters on average provide savings of €160 for gas and €309 for electricity per metering point (distributed amongst consumers, suppliers, distribution system operators, etc.) as well as an average energy saving of 3%.

The USmartConsumerProject (2016) maps the smart meter landscape in European countries. However, it must be pointed out that the project is limited to smart metering for electrical consumption only. In their study they have analysed and classified the EU countries along two dimensions. The first is the legal and regulatory status: Is there a framework to provide clear guidelines for installing meters and does this framework supports the goal of achieving energy savings and/or demand response effects for the energy consumers? Progress in market implementation is the second dimension. Here reference is made to the existing number of smart meters and corresponding services and the existence of a clear, realistic national implementation roadmap for metering technologies. Figure 2 pictures the situation in 2016. On the basis of these dimensions the EU Member States are classified in 5 groups:

- Front runners.
- Dynamic movers.
- Market drivers.
- Ambiguous movers and
- Waverers.

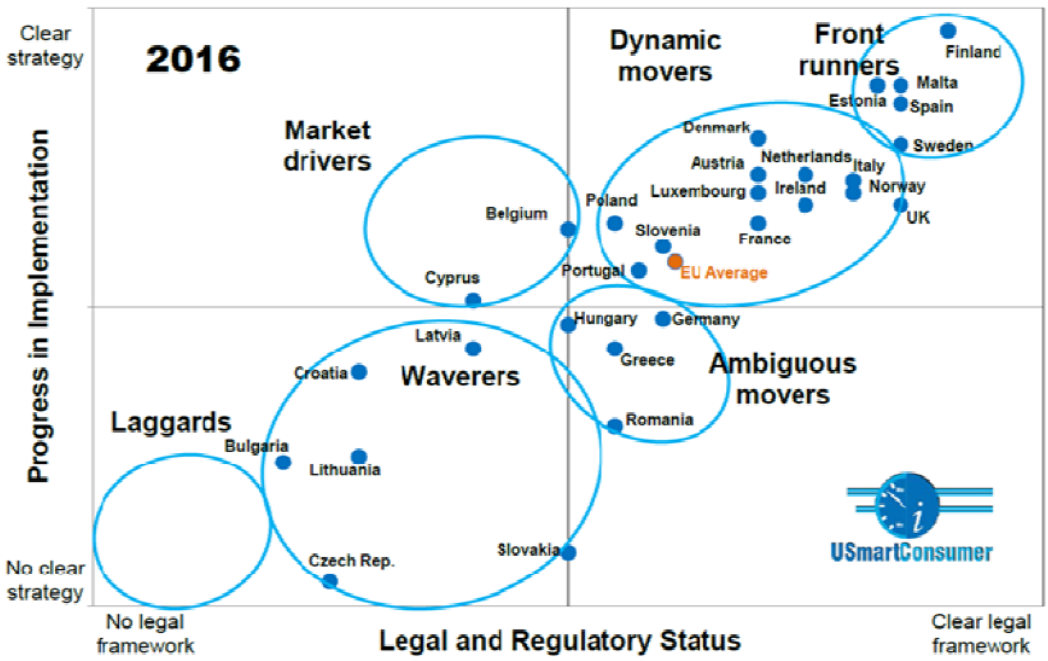

Figure 2: Legal, regulatory and marketing situation in the European smart-metering (for electricity consumption) implementing process. Source: USmartConsumerProject, 2016.

Figure 2 shows that from the Triple-A countries the UK, the Netherlands and France are being categorised (together with more than 50% of the EU countries) as ‘dynamic movers’. Belgium is being considered as a ‘market driver’ in 2016, however it nearly confluences with the ‘dynamic mover’ countries.

Dynamic movers are characterised by different features. They must have a mapped clear path towards a full rollout of smart metering. Either the government has already made a decision for a mandatory rollout or major pilot projects are underway paving the way for such a decision. Smart metering services are already offered to consumers and the actual rollout is in progress.

Market drivers are countries that have not yet set legal requirements for a rollout. Nevertheless some energy suppliers or other companies are busy installing smart meters either because of internal synergetic effects or because of customer demand (USmartConsumerProject, 2016). In the meantime the government of Flanders has adopted plans for a rollout of digital meters (see section 4.2), so it can be assumed that Belgium has now joined the group of ‘dynamic movers’.

In some countries first mechanical analogue meters are replaced by digital meters. A digital meter uses electronics and a digital display to replace the old mechanical meter with the turning gears and dials. It's easier to read, harder to misread. But it still needs to be read by an actual meter reader. A smart meter adds communication ability. It allows the meter to be read remotely, by a computer. In the Netherlands people are allowed to switch off the communication port of the smart meter, so the actual meter reader still has to come to read the meter.

5.2.1 Netherlands

The Dutch Parliament decided in 2011 to introduce standardised smart meters both for electricity and gas. The idea was to implement the introduction via a two stage approach. Between 2012 to 2014 smart meters were only installed in new constructions, large-scale renovations and as replacement of broken existing meters. This is and will be followed by a large scale rollout in the period 2015-2020. This distinction between two stages was made to get insight in the results and the rollout experiences in stage 1. These insights were necessary to provide adequate input to the parliament to make a decision about the large-scale rollout in the second stage (Van Elburg, 2015).

It was estimated in 2010 that the smart meter (combined with sophisticated feedback) could result in average savings of 6.4% for electricity and 5.1% for gas (Van Gerwen et al., 2010). Empirical research (see also chapter 2) showed that the actual energy saving results appeared to be lagging behind. The government decided to accelerate the rollout, aiming to have a smart meter installed at least 80% of the households in 2020. In 2014 additional regulations were implemented to stimulate the rollout of smart meters from 2015. From that year on network operators are (statutory) mandated to provide smart meters to households, who have the choice to accept or refuse the meter. When accepted, the network operator is authorised to collect and use the usage data for (amongst others) billing, etc. On the other hand they must provide the customer with (bimonthly) consumption and cost date. It is considered the responsibility of the market to provide households with more (e.g. real time) information about consumption and costs.

At the end of 2016 it is estimated that around 3.0 million households have a smart meter. The number of smart gas and electricity meters is predicted to exceed 8 million households by 2020 (USmartConsumer, 2016). This would more or less mean that all Dutch households will have access to a smart meter. This expectation is supported by Vringer and Dassen (2016) who also expect that all Dutch households will have a smart meter by the end of 2020.

5.2.2 Belgium

In Belgium policy regulation about the rollout of smart meters is lacking until today (Vringer and Dassen, 2016). Both federal as the highly autonomous regional governments share the responsibility for formulating and implementing energy policy. The introduction of smart meters is seriously delayed in the beginning of 2014 because the outcomes of the cost benefit analysis (CBA) in the three regions conflicted with each other. Flanders carried out two CBA’s with variable results (depending on various scenarios and conditions). The outcome of the CBA in the Brussels Region was negative. In Wallonia the CBA for a full rollout was negative, while a ‘smart meter friendly scenario) had a positive outcome (USmartConsumer, 2016).

In Flanders the VREG[5]-scenario from 2014 for a segmented rollout of smart meters showed positive results (contrary to a scenario for a complete rollout). This is related to the fact that energy consumption tariffs differ according to a legal social classification system. Consumers that are eligible for higher tariffs consequently can benefit more from the introduction of smart meters than low tariff consumers (USmartConsumer, 2016).

In 2017 the VREG made an updated cost benefit analysis (VREG, 2017) that showed that a complete rollout of **digital meters** over a period of 20 years yields positive results for the entire society. An important note is that the effects can differ per customer type and between active and less active customers. The first meters already were installed in 2016 as pilot projects in a limited number of municipalities. The network operator and local authorities decided which municipalities/districts participated in the pilot project. The Flemish government plans to install the digital meters throughout Flanders from 2019 onwards. They will first be installed by (re) builders, owners of solar panels and customers with a budget meter. Households that fall outside these target groups can apply for a digital meter from 2019 onwards. The households have to pay the costs for installation, commissioning and the meter. Although there are certainly benefits for the consumer, the main advantages of the digital meter are apparently for the grid operators (the data are automatically forwarded to the operator; shutting down or reconnecting to the network can be done remotely; suppliers can work with a smart meter with a prepaid system). The consumers have the possibility to extend the digital meter to a smart meter and follow-up of their own consumption in real time (e.g. with a smartphone). They can consume energy when the power is the cheapest or consume energy they generate themselves (e.g. solar panels), and determine the optimum moment to sell surpluses of self-generated energy.

5.2.3 UK

The UK government decided early 2011 on the rollout strategy and policy design for smart meters (USmartConsumers, 2016). Since then the rollout program has been changed significantly. The updated plan expects the rollout to start late 2016 and be completed by the end of 2020. This would mean that by the end of 2020, around 53 million smart meters should be fitted in over 30 million premises (households and businesses) across Wales, Scotland and England. The programme is already underway (Smart Energy GB, 2018, website).

[5] VREG=Vlaamse Regulator voor de Elektriciteits- en Gasmarkt or in English: Flemish Regulator for the Electricity and Gas Market.

Besides the department responsible (Department for Business, Energy and Industrial Strategy) several other organisations are involved in the process: energy suppliers, smart Data Communication, Company (DCC), the national energy regulator (Ofgem), distribution network operators and Smart Energy GB (a non-profit organisation responsible for marketing and public campaigns).

For households smart meters are optional and for free and they all must be offered an in-home device. Many suppliers also offer free online and phone app options for energy management (USmartConsumer, 2016). The actions of Smart Energy GB have increased the consumer awareness of smart metering. Around 31% of British households know about smart meters and 21% want to upgrade or already have a smart meter.

According to the department responsible good progress continues to be made on the rollout of smart meters, with the latest statistics showing over 8.6 million smart and advanced meters operating across homes and small businesses in Great Britain up to 30 September 2017 and a total of 3.3 million meters installed in the first three quarters of 2017 (DBEIS, 2017).

In the UK installations of **smart meters are combined with installations of in-home displays**. These displays can take different forms and it is up to the energy supplier what type of display they choose to provide the household with their smart meter. All types of in-home display involve a handheld digital device that sits in the home and the household can see what they are spending (https://www.smartenergygb.org/en/how-to-get-a-smart-meter/the-installation-process).

5.2.4 France

In September 2010 the French government issued a Decree that defined the terms of a mandatory rollout of **smart electricity meters** in France (USmartConsumers, 2016). This decision was based on the results of a pilot project undertaken by Enedis (at that moment known as ERDF) with their smart electricity meter called 'Linky'[6]. Linky is a communicating smart meter, which can receive and send data without the need for the physical presence of a technician. Installed in end-consumer's properties and linked to a supervision centre, it is in constant interaction with the network operator. The billing is based on the actual electricity use. As with all the other smart meters in general in Europe other advantages for consumers that they may stimulated to save energy or undertake energy saving measures.

The initial pilot phase took place in 2009 and 2010 in which over 250 000 Linky meters were deployed in the urban greater Lyon area and the rural areas in the Indre-et-Loire regions (Enedis, 2018, website). From 2012 on all new electricity meters that are installed must be smart. The national deployment campaign began in December 2015. A detailed rollout timetable is accessible on the website of Enedis. At the end of 2016, 3 million meters have been installed. The goal is to install 28 million meters by the end of 2021. Within the EU smart metering programme France has committed itself to 95% smart meter penetration by that year. Contrary to some other EU countries (e.g. UK) French households are obliged to let an installer install a smart meter in their house. The installation however is free of charge.

GDRF undertook a pilot with 'Gazpar' **smart gas meters** between mid-2010 and mid-2011. Around 18,500 smart gas meters were installed in that period. In the same period a start was made with modernizing and developing the gas network not only with Gazpar meters but also with smart pipes and smart gas grids. The goal was to improve the control of consumers over the energy they use by making more frequent updates on data consumption available (via Gazpar), and to optimize the distribution network by modernizing and improving performance of the natural gas distribution grid. A start was made with the modernisation of the gas network in consultation with local and national public authorities. After final validation of the Project by the French Ministers for Ecology and Economic Affairs in 2014, 150.000 smart gas meters were installed in 24 pilot municipalities in four French administrative districts (Côtes d'Armor, Hauts-de-Seine, Haute-Normandie and Rhône) in 2016. In 2017 the French government provided the further rollout of the gas meters with regulatory approval. The first rollout of the Gazpar smart gas meter started during

[6] ERDF (Électricité Réseau Distribution France) changed its name in Enedis in 2016. Enedis is the distribution grid operator for electricity in the majority of France (95% of the country). The distribution system operator for gas in the vast majority of France is GRDF (Gaz Réseau Distribution France). Besides those two some local distribution system operators for electricity or gas and sometimes both (known as ELDs: Entreprises Locales de Distribution) are active in France. This is still a legacy of the past were cities detained the electricity and gas distribution grids in France. Currently these ELD's represent around 5% of French territory. (Selectra, 2018, website)

2017. This should eventually result in 11 million Gazpar meters to be rolled out throughout France between 2017 and 2022 (GRDF, 2017).

5.3 Diffusion of HEMS in Triple-A partner countries

5.3.1 Netherlands

In the Netherlands HEMS generally are named '**energieverbruiksmanagers**' or '**energiemanagers'**[7]**.** The web site 'energieverbruiksmanagers.nl' (retrieved March 2018) gives an overview of 42 products that can be used in combination of smart, digital and analogue meters (in combination with an analogue meter 12 products are available), for gas and electricity use, heat and electricity and solely electricity, having or not solar panels, and for specific functionalities. The functionalities are:

- Insight in real-time energy use
- In-home display at the wall
- Energy consumption data appliances
- To be used regardless the energy providers (if yes 37 products remain).

Five products solely can be used in combination with an energy contract of an energy provider, being BOKS (Greenchoice), Essent Thuis App (Essent), Mijn Nuon App (Nuon), Oxxio App (Oxxio) and Eneco App.

Another HEMS comparison website is 'energiemanagers.eigenhuis.nl' (retrieved March 2018). In addition to the website 'energieverbruiksmanagers', 46 products are reviewed. The above mentioned functionalities can be distinguished, but there are interesting extra functionalities:

- Is water usage included in measurement?
- Can electric car charging be monitored?
- Can energy consumption be analysed?
- Thermostat functionality.
- Free to use or are costs involved.
- Privacy, defined in five degrees (although criteria are not clear).

Free of charge are 16 HEMS, especially Apps that show the energy consumption of the day before.

An overview of smart thermostats in the Netherlands is given by Milieucentraal. The web site 'milieucentraal.nl/energie-besparen/energiezuinig-huis/energiezuinig-verwarmen-en-warm-water/slimme-thermostaat' (retrieved March 2018) displays the specifications of 14 smart thermostats.

5.3.2 Belgium

In Belgium HEMS generally are named '**energiemonitors**' (website ecobouwers). Eandis listed four energy monitors, five smart thermostats, and one combined smart thermostat and energy monitor, namely Boxx (Overview Flanders Eandis, Amiens meeting, 2017).

EANDIS offers the **web platform E-lyse** to homeowners that renovated their house via collective projects (Burenpremie-project) and to energy renovation consultants (BENOvatiecoaches) to monitor energy consumption (website EANDIS).

In Belgium there are 3 well-known systems of HEMS: June, Smappee and Fifthplay (Smappee is also listed by energieverbruiksmanagers.nl) (Information City of Antwerp and EOS, 2018).
June is a tool taking pictures of the consumption values that is installed on an analogue electricity/gas (optional water) meter. The pictures are transferred to a gateway that is connected with the June user platform (website). The user can follow-up on his/her energy consumption on a daily basis, with a split-up between day and night (if double day/night tariff is applicable). Energy

[7]. Zie bijvoorbeeld http://www.technischwerken.nl/kennisbank/duurzaamheid/wat-is-een-energieverbruiksmanager/

usage is displayed in kWh, comparison between two periods is possible. June has so far no sensitization via the platform. So the behaviour of home-owners will probably change less. June has its own platform, but it is looking to connect with other platforms like “Energie-ID”. They offer a switching service where June switches the home-owner to the cheapest energy provider. In the future they want to expand and offer more services. Home-owners pay a monthly contribution of €4,99 for this service. The installation of the meter readers is very easy. You don’t need to open your electricity cabinet and you don’t need a socket or Wifi close to the meters. The meter readers work with rechargeable batteries that has to be charged +/- once a year. So they can be placed in almost any kind of situation.
Smappee is a complete energy management system for electricity, gas, solar panels and water. It gives insight in real-time energy consumption and production (solar panels), big energy users and slumber consumption. The user interface is an own dashboard and App. The installation of Smappee is with a clip-on sensor on the main cable and an energy monitor. This sensor can detect the main household appliances. A sub measurement is possible with extra clamps. With these clamps you can detect difficult to detect appliances like an electric car or a heat pump. Appliances that are connected to Smappee can be switched on and off through the App even if these appliances are not smart. Smappee works independent of the energy supplier. The installation is a bit complex. The meters have to be near the electricity cabinet and a socket is needed to plug in the energy monitor. Installation by an electrician can be needed. The cost price is quiet high. Peer-to-peer trading with block chain technology is possible.
Fifthplay is a smart system that automatic identifies the different appliances, gas and water. The user interface is an own dashboard and App. Fifthplay works independent of the energy supplier. The Installation is with smart plugs and a bit complex. One can install a smart switch for lighting and smart plugs to measure separate household appliances. The cost price is quiet high.
Netatmo is a smart thermostat that replaces the conventional thermostat and can be installed both wireless and cabled. The device can be controlled remotely via a website and/or a mobile app. Temperature settings can be adjusted locally as well via the in-house display. Both the website and the mobile app offer reporting functionalities (including e.g. month-by-month comparison) and various options to adapt settings of the heating system, as well as tips & tricks on energy saving or alerts in case of malfunctioning.

5.3.3 UK

There is no standard or recommended lists of the different technologies and suppliers available in the UK. A simple internet search identifies potentially hundreds of different options. The UK Government provides general guidance on smart meters via its website, in support of the national rollout of smart meters via energy companies (gov.uk/guidance/smart-meters-how-they-work) but this does not include an endorsed list of the types of energy monitors available. The endorsed government approach is to contact your own energy supplier as the main market players for these devices.

5.3.4 France

Energy provider EDF has offered a new free dashboard called "e.quilibre" to monitor electricity consumption since March 2015. To use e.quilibre, the users must have electronic electricity meters. Most of electricity meters in France are still electromechanical ones. e.quilibre is available as a free application to download on a smartphone or tablet or as a feature in the personalised web site. The registration to the service requires some information and a detailed questionnaire which will then make it possible to define needs and habits of consumption: size of the housing, number of rooms, type of heating, number and nature of the electrical appliances, electronic equipment, present times at home, etc.. The application then automatically generates diagrams and charts that allow, among other things, to track consumption in kWh and Euros on a monthly or annual basis.

E.quilibre has been particularly successful: already 10 million profiles have been created in total, which represents 25 million private users (with an average of 2.5 people in a home). A smart thermostat (Netatmo) could be integrated (Amiens meeting, 2017).

Energy provider EDF and a start-up offer the tool **SOWEE** for bundled offer green gas and electricity, and energy use monitoring by an App. It can also steer the heating to a wished cost regime, arrange the charging of a vehicle and the energy production of solar panels. Next it can give feedback on the air quality (Amiens meeting, 2017).

Just like e.quilibre, Energy provider GRDF, offers smart gas meters (Gazpar) allowing energy monitoring of homeowners. Households equipped with a Gazpar meter are able to consult their daily consumption via their GRDF Customer profile, available on the internet and on a dedicated application for smart phones or tablets. In addition, it allows to:

- set a certain predefined consumption threshold to send an automated alert of exceeded;
- to compare consumption with those of similar profiles. It implies to fill in a questionnaire about habits of consumption and the type of house.

5.4 Local authorities and the use of HEMS

The use of smart meters and HEMS and providing easy access to HEMS to homeowners could be one of the instruments of local energy saving programs and community-based reinforcement strategies. A neighbourhood approach aims to enable more positive outcomes for energy savings and uptake of renovation measures, by using peer-to-peer communication, personal advice, trialling in demo houses and demonstration in pop-up centres and on local authority websites.

Those strategies could inhere the installation of smart grids to make optimal use of (green) energy. This enforces the cooperation between local authorities and network operators. Research showed that the use of smart home automation systems could have a positive environmental impact by decreasing the peak load and shifting part of the energy consumption from daytime to night-time (Louis et al., 2014)

Here there could be a link to other local programs like ‘future proof living’ and the use of domotics or smart home automation for e.g. save and comfortable living and offering care services.[8] In this case a HEMS can function as a central hub that supports much more functions than monitoring energy and comfort.

Interesting is a study by Louis et al. (2015) about environmental impacts and benefits of smart home automation. They argue that the issue of electricity demand of smart control devices itself should be more present in the discussion about smart home automation; the balance between what actually need to be controlled and the resulting energy consumption of the control system. The largest part of HEMS electricity consumption is due to smart plugs. According to manufacturers’ data a smart plug consumes 4 W constantly.

[8] The word “domotics” is a contraction of the Latin word for a home “domus” and the words informatics, telematics and robotics. Our definition of domotics or home automation is: “The integration of technology and services for a better quality of life.” Home automation is not just the integration of technology and control in the home, but it also covers outside services that are brought into the home. (website smart—homes.nl).

6. Specifications of HEMS

6.1 Introduction

Energy savings influenced by HEMS vary widely. A reason is that HEMS vary widely in their design and features. Kobus (2016) poses it as: “It is not about the question does feedback work, but how can we design systems that make feedback work?” Essentially, a HEMS is a system that gives easily accessible insight into and control over a household’s energy consumption.

In the EU-directive on energy efficiency (EU, 2012) a smart meter is defined as an electronic meter that measures energy consumption and can transmit these data using a form of electronic communication to give feedback about actual residential energy consumption and costs with the intention to encourage households to lower their energy use. But, a smart meter is not a necessity though to give users feedback about their energy consumption. HEMS could be defined as devices that give computerised real-time (visual) feedback on gas and/or electricity consumption (Van Dam et al.; 2010; Kobus, 2016). In the Triple-A project HEMS are being defined as:

- HEMS is **a metering device with a communication to a display unit in the house or to a smart phone/tablet (App)** (D.4.4.2 Protocol: monitoring energy savings in dwellings; 3.2.2 Actual data A1 HEMS method)
- “Monitoring Equipment” or “HEMS” (home energy monitoring system) means **electrical instruments that record characteristics of electrical power into and out of the Pilot Property, PV and Battery including but without limitation voltage, current, kWh, kVAr, kVA, time of use, harmonic distortion etc.** (The Triple-A Project, Domestic Energy Storage System Trial, Pilot Properties – Resident Terms and Conditions, Kent County Council, December 2017).

6.2 Classification of HEMS

In Table 3 we classify the use functions of the technological systems that may belong to a HEMS.

TABLE 3: USE FUNCTIONS HEMS PER SYSTEM

System	**Use functions**
Smart meters (electricity, gas, heat)	**Monitoring energy, gas and heat use**
	Indirect data feedback user (enhanced billing)
	Energy consumption analysis LAs
	Follow-up renovation / post-work monitoring LAs
Smart meter(s) + user interface	**Monitoring energy, gas and heat use for feedbakc end-users**
In-home display	Direct visual real-time data feedback end-user
Web / App	Direct visual real-time data feedback end-user
Energy portal / Load monitor	Enabling remote or rule-based control
User interface without Smart meter	Direct visual data feedback end-user
Smart technologies	**Remotely control devices by end-user**
smart thermostat	setpoint fixed / dynamic
smart lighting	settings
smart plugs	on/off appliance
smart household appliance	on/off appliance
Smart home platform (integrated systems, domotics)	**Energy management by end-users**
	Enabling a standard way for devices and appliances to interact
	Use of renewable energy own house, e.g. charging and discharging batteries
	Use of renewable energy, smart grid
	Linking dynamic pricing schemes
Users platform	**Informing (comparing data) by end-users**

The specifications of HEMS concern smart meters and user interfaces.

6.3. Use of HEMS by Triple-A Local Authorities

LAs need to check for what purpose they intend to use the HEMS. See Table 4.

TABLE 4: QUESTIONNAIRE HEMS LOCAL AUTHORITIES, FEBRUARY 2018

	Antwerpen	Breda	Kent	Mechelen	PSEE	Rotterdam	Oostende
For what purposes will you use HEMS?							
Help users to better manage their energy consumption	■	■		■	■	■	■
Help users to better understand their house		■			■	■	
Control the energy consumption (before and) after executing works	■	■		■	■	■	
Manage heating system						■	■
Others :			■				
Main functionalities required for the system?							
Collect data about house comfort					■	■	
Users interface to have an access to the collected data	■		■	■	■	■	■
Users interface with advices on energy consumption - use of equipments					■	■	■
Users interface with advices on energy consumption - after executing works	■				■	■	
Admin interface to access data and make analysis	■		■	■	■	■	■
Data to be collected (measured or declared)?							
Electricity consumption	■	■	■	■	■	■	■
Gas consumption	■	■		■	■	■	■
Oil consumption							
Wood consumption	■						
Electric production	■	■			■	■	■
Comfort temperature - in one location					■	■	■
Comfort temperature - several locations					■		
Humidity rate in the house - in one location					■	■	
Humidity rate in the house - in several locations					■	■	
Water consumption						■	
Hot water consumption						■	
User interface, important functionalities? 1 = very important / 5 = not required							
intuitive	5	3		3	1	1	1
easy to use	1	1	■	1	1	1	1
access to all measured data	2	2		1	2	1	3
access to real-time data	1	3	■	3	2	1	4
possibility to make manual recordings (e.g. for wood or oil heating system)	5	5		5	2	?	3
decomposition of consumption by type of use	5	3		3	2	2	4
possibility to fix an objective in terms of annual consumption	4	4		3	1	2	5
access to comfort data	3	3		3	2	2	4
access to data for comparison with equivalent houses data	1	2		1	2	2	4
alerts in case of consumption deviation	3	1		2	3	3	2
eco-coaching' pages: advices on energy savings	4	2		1	3	3	2
possibility to edit reports (monthly, annual...)	2	3		1	2	2	2
possibility to export data (to make analysis)	2	2		1	2	2	2
future consumption prognosis	5	3		2	2	2	5
User interface to be consulted?							
on a specific display unit		■	■		■	■	■
on a website	■		■	■	■	■	■
on a mobile app	■		■			■	■
Important or not?							
The system should be suitable whatever the energy supplier	Y	Y	Y	N	Y	Y	Y
The system should be suitable whatever the consumption meters	Y	Y	Y	Y	Y	N	Y
The system should be compatible with smart meters	Y	Y	N	Y	Y	Y	Y
The application should be suitable with all kind of consumption tariffs	Y	Y	Y	N	Y	Y	Y
What type of HEMS do you intend to implement?							
Smart meters					200		
Smart meters + user interface	■				200		
Consumptions and comfort sensors					200		
Consumptions and comfort sensors + user interface					200	20	
Smart hardware (thermostat, lighting, plugs, household appliances...)		85			0	10	50
Smart home platform (integrated systems, domotics)					0	10	
Users platform (Informing (comparing data) by end-users)	■				200	10	
How many systems does your LA intend to implement in the demo exemplars?							
in 2018	2	25	10	50	60	50	?
in 2019	4	60	0	50	80	50	?
in 2020	4		0		80	50	?

Clearly, the purposes and required functionalities of the HEMS differ per local authority.

In **Kent**, Local Authorities have started to compare and contrast different types of Home Energy Monitoring and Management Systems (HEMS). In one study in Dartford five types of HEMS are compared (Energy Enterprise and Education (E3) Limited (2017).

Through Triple-A, Kent will be looking to utilise HEMS to understand the overall benefit to domestic properties in financial terms, from utilising battery systems in tandem with solar panels. Kent seeks to establish a detailed understanding of the pattern of energy use within the property, how the technologies perform and ultimately how they are used by residents to maximise the efficiency of their energy use.

PSSE, Rotterdam and EOS (Oostende) would like next to energy use also to monitor comfort data.

PSEE will use the **Quart'Home Monitoring System** , offered by Quartum/EcoCo2. The software is patented by Quartum and developed by EcoCO2 which ensures its maintenance and evolution. The system has been developed and tested during the TBH project (Tableau de Bord de l'Habitat) supported by ADEME and the French government support program "Investissement d'Avenir". The Quart'home system helps homeowners to understand, monitor and reduce their electricity consumption by displaying multiple data: power, load curve, electricity and gas consumption, indoor and outdoor temperatures, indoor and outdoor humidity, comfort zone diagram and advice offered by "eco-coaching". Feedback is given on a tablet connected via WiFi. An account has to be created on the Quart'Home website to have all information about the house, occupancy, energy consumption, etc. on one place. The homeowner has a contract with Quart'Home to assure data privacy.

EOS performed tests with the **digital meter reader June** and **smart thermostat Netatmo** (See Descriptions 4.3.2). As the June equipment was originally developed to help people switch between energy suppliers (based on their energy consumption and energy prices), there is very limited interaction with the user (no alerts or tips & tricks to influence the user's behaviour). Therefore, this device seems less useful to sensitize people about their behaviour and/or possible energy savings. EOS has quite some experience with Netatmo for energy monitoring and remote control of heating installations. Based on the tests with both solutions, EOS will use the Netatmo smart thermostat to manage/monitor gas consumption for heating and to sensitize people about their energy usage. One part of the smart thermostats will be distributed via the social housing company of the City of Ostend (comparable types of homes, less conscious of energy savings). The HEMS will also be promoted in the movable pop-up visiting the neighbourhoods of Ostend, in order to have them installed in different housing types.

The **City of Antwerp** wants to give insight to home-owners in their energy consumption. But it also wants to control the energy reduction before and after executing works to see what the (technical) performance is of the taken measures. Antwerp had a meeting in 2017 with the company that provides the digital meter reader **June**. Antwerp is testing **Fifthplay** and **Smappee**. Below you find a list of the characteristics of each system.

6.4. Specifications

Generally, the implementation of the Triple-A HEMS should appeal to (1) **end-users (households)** and (2) **local authorities**. Triple-A partners will provide HEMS to households to encourage them to change their energy behaviour and to trigger interest in the adoption of low carbon technologies. Another goal is to apply HEMS in demonstration exemplars (WP 4) to monitor the energy consumption of households and analyse consumption data before and after applying low carbon technologies.

Based upon the literature review we can conclude that for end-users:

- HEMS should be easy to use and accessible, and fit for purpose;
- Feedback should be real-time, frequent feedback enables the user to link behaviour to consequences.
- The specifications of the HEMS should match with the household characteristics and the willingness to use HEMS. A distinction between user groups is advisable: some users explicitly have more interest in more functionalities (and thus a more complex HEMS, others want a more intuitive user interface.
- It is unclear if adoption of HEMS will lead to the adoption of important renovation measures.
- HEMS should appeal to certain conditions of the homeowner (segments) or to solving issues within the home.

Based upon the approaches chosen by the Triple-A actors specifications for HEMS include:

- The HEMS should be cost-effective.
- The installation of the HEMS should be easy (preferentially without electricity connection).
- The intrusion time for installing in the home should be minimized.
- A preference is given for HEMS that local authorities can experiment with free-of-charge to avoid de minimis statements.
- HEMS choice by local authorities will be influenced by the need to follow-up KPI's for energy saving, and thus the compatibility with their own energy management system for analysing building stocks.

6.4.1 Mandatory functions and baseline requirements HEMS

According to D.4.4.2 Protocol: monitoring energy savings in dwellings, baseline requirements HEMS to monitor actual CO_2 savings by LAs within the demonstration areas are:

- Recording (or accessing data related to) **annual energy use** gas and/or electricity within the properties for a period of 12 months pre and post installation

Specification energy data to meet Triple-A Basic requirement

- Frequency recording: < … min
- Level of accuracy: ± …%
- Resolution: 1 Wh
- Acceptable level of downtime over the course of 12 months

Data transfer

- Internet-based: internet connection homeowner
- Internet-based: internet connection hotspot
- Mobile data transfer (3G or 4G)

Data sharing and privacy issues

- Accessibility data for end user
- Accessibility data by third parties
- Storage data
- Online connectivity Need for WIFI
- Data send by WWW

Specifications administrative interface

- To have access to data and to analyse the data

Compatibility system

- with energy supplier
- with meter type electric, gas, heat, water (analogue, digital, smart)
- with consumption tariffs

Continuity and reliability of data

- Robustness of system and data transfer and storage

HEMS will also be used to give real-time feedback energy-use to homeowners helping them to manage their energy consumption.

Specifications users-interface

- To have access to the collected data *Type of feedback is up to partners (see 5.5.)*

6.4.2 Discretionary functions and requirements HEMS

Below discretionary functions and requirements of HEMS are listed from which LAs can choose from. The list is not exclusive.

Billing system

- System enables remote billing of end users for system or energy generated

Installation, operation and maintenance system

- Easiness of installation
- Installation can be completed by the end user (or battery installer)
- Maintenance-free
- Remote accessibility to maintain
- Helpdesk provider HEMS

Monitoring energy data

- Grid energy monitoring: ability to record electricity usage from the grid
- Solar PV monitoring: ability to record electricity generated
- Gas monitoring: ability to record gas usage
- Heat monitoring: ability to record heat usage

Identification, monitoring electricity usage and remotely control devices (appliances/smart thermostats), electric vehicles

Identification and monitoring: ability to record electricity usage devices/appliances (*and provision of information to end user about individual energy using devices/appliances→ user interface*)

- Identification, monitoring and remotely control appliances on/off (smart plugs)
- Identification, monitoring and remotely control lighting settings (smart lighting)
- Identification, monitoring and remotely control thermostat function (set points) (smart thermostat)
- Identification, monitoring and remotely control electric vehicles

Other household appliances could be e.g. fridges, washing machines, .. (with Wifi connection)

Monitoring, control storage system batteries homes and electric vehicles

- Battery performance monitoring: ability to record energy stored in and discharged from the home batteries
- Battery performance monitoring: ability to record energy stored in and discharged from the electric vehicle batteries
- Storage System Control for Grid Services: ability to remotely override control of the battery to enable services provided to the network operator

Monitoring comfort data (sensor data)

- Internal and external temperature: ability to record internal and external temperature
- CO_2 concentration: ability to record CO_2 concentration
- Internal and external humidity: ability to record relative humidity level
- Presence: ability to record presence in rooms
- Smoke detection: ability to detect smoke

Others comfort data smart homes

Specification recording comfort data (frequency, level of accuracy, ...)

- Internal and external temperature:
- CO_2 concentration: Rooms?
- Internal and external relative humidity: Rooms (special sensor bathroom)?

- Presence: Rooms (PIR presence infra-red)?
- Smoke detection: Rooms?

Monitoring water data

- Water monitoring: ability to record water usage
- Hot water monitoring: ability to record hot water usage
- Solar hot water monitoring: ability to record hot water generated

User interface

- Internet based: Ability for homeowner to acquire information using internet connected device
- Smart phone app: Ability for homeowner to acquire information using dedicated smart phone app
- In home display: Ability for homeowner to acquire information using dedicated screen within property

Data analysis end users (user interface)

- Provision of information to end-user about energy use per month, day, hour
- Provision of information to end-user about energy use is cost per month, day, hour
- Provision of information to end user about individual energy using devices
- Selection periods for comparison
- Provision for target settings
- Comparison energy use with target settings
- Comparison energy use with other users
- Alerts in case of consumption deviations from target settings
- High use alert
- Future energy prognosis
- Cost savings by energy savings prognosis

Data analysis end users reporting(user interface)

- Standard reports
- Provision to edit reports
- Provision to export data for reports

Advice energy use (user interface)

- Standard advice on energy savings (eco-coaching pages)

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