

# INSIGHTS IN USING HOME ENERGY MANAGEMENT SYSTEMS

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## Abstract

In an ongoing process, three diverse Home energy management systems (HEMS) have been implemented in households in the Netherlands. Through a series of questionnaires, interviews, focus groups and usability tests, a wide range of knowledge is being gathered. Because of this broad approach, the insights that are gained are not only limited to the amount of savings that were achieved but also encompass participants understanding of, and control over, their home energy consumption and the manners in which the HEMS is incorporated into their daily lives. This paper presents the first insights that were gathered through the in-depth contact with users. It aims to provoke an open discussion to further the development of the insights into guidelines for effective and useful HEMS.

## Keywords

*Home energy management systems, energy monitor, energy saving, conservation, household*

## **1. Introduction**

Home Energy Management Systems (HEMS), e.g. energy monitors, are intermediary products that can visualize, manage, and/or monitor the energy use of products or whole households. In recent years numerous companies worldwide have become interested in developing HEMS or executing field studies with them. Current research is directed towards the potential for HEMS in reducing energy consumption within the home. Some studies have reported positive results, at least in the short term, but in the majority of cases HEMS were less successful or failed outright. Based on three case studies that were executed by the author since 2008 and knowledge from literature, this paper presents a number of insights intent on increasing the effectiveness of HEMS. All three case studies are a joint cooperation between energy companies, HEMS manufacturers and Delft University of Technology with a different HEMS being applied in each case study. The first quantitative case study (van Dam et al., 2010) was executed in 2008 and 2009. The second and third case studies are currently underway; one with an electricity monitor giving disaggregated feedback and the other with a gas and electricity monitor. The qualitative data from these cases, which was gathered in the spring and summer of 2010 through usability tests, focus groups and in-depth interviews, has been analysed. The observations have led to a number of insights on the design and implementation of HEMS and the role they can play in households, which are presented in this paper. As these insights are based on work in progress, this paper would like to initiate a discussion as to their worth and correctness.

## **2. HEMS design and tailoring**

If HEMS are to fulfill their purpose, namely to help households save energy, they must indeed be used by households. To understand if and how they are used and experienced, the insights from users are vital. In the case studies, working with users and talking to them through semi structured in-depth interviews proved very insightful.

### **2.1 Usability should be given priority**

The very first energy monitor was introduced more than three decades ago (Funk, 1978), and the first gas monitor in the Netherlands in 1982 (van Beurden, 1982). While this seems to indicate that by now the technology should be fully mature, the real technology development seems to have accelerated only in recent years as numerous new companies have been coming to market. Even now, technical hiccups are still commonplace in commercially available HEMS. It is likely that the immaturity of the technology is an important reason for the lack of attention for usability and interfaces. This is however a bottleneck for the commercial success of HEMS. The majority of HEMS have a very

'technical' interface. Kidd and Williams (Kidd and Williams, 2008) reported a participant saying "I certainly haven't used it. . . . I certainly am not techno..." And in Van Dam (2010), a participant in a usability study said: "It is all numbers; it doesn't mean anything to me". Improving the usability and the interface is essential to making HEMS a mature and successful product.

## **2.2 One size does not fit all**

Users are 'wired' differently and have different needs and expectations. They are also seen to use HEMS in different ways. Liikanen (2009) found three distinctly different types of users, with different attitudes towards energy monitors: wisdom seekers, detectives and judges. Each 'type' of user was looking for different kinds of feedback. Obviously, this has consequences for how HEMS should be designed. In our case studies, similar user preferences surfaced. Some participants had a preference for feedback at household level while others wanted data on each individual product (disaggregated feedback). In one focus group amongst users of the gas and electricity monitor, one female participant wanted to know 'everything': each detail as to the consumption of every appliance, while another female participant indicated that an overall indication of total consumption was quite enough for her.

The (visual) communication methods used in HEMS should accommodate the significant variation in users' capacity and manner of cognitively processing information. Where possible, this should not be limited to visual communication methods. Some users prefer numerical facts and figures; others want abstract indicators (i.e. colours). As one usability participant said: "So then with numbers saying 'you're using this much' or 'you have burnt this amount of gas' or whatever, yes well... A bit of comfort for oneself is also pleasant. So then those numbers don't really mean anything to me... I think colours more. More than numbers." Another participant indicated: "If I think it's too warm in the house and I hear 'click', then I know that someone has altered the settings of the thermostat. And then I say 'who touched the thermostat?'" This participant used the 'clicking' sound of his current thermostat as an auditory prompt.

The design of HEMS should consider that user's depth and understanding of energy and their desire for insight varies greatly. The design should therefore probably be layered, providing simple information at a quick glance and increasing the depth of information in ensuing steps. HEMS are well suited for simple, easy-access information. However, information overload is a risk within the small physical boundaries of a HEMS monitor. Rather, HEMS should be approached as a *system*, where users are led to other media for further analysis of in-depth information when wanted.

## **2.3 The energy enigma**

It should not be considered as a given that users have a (correct) conception of what a kWh or m<sup>3</sup> entails, nor that they know what to do with that information. Two of the 14 participants in the usability study had difficulties understanding m<sup>3</sup>. One said, “what does ‘m’ ‘3’ mean”? A second person asked: “It says here 2 uhmm... How do you measure gas again? Cubic or something?... Yes, it says 2 ‘m’ ‘3’” Noteworthy, both participants knew the wattage of their coffee machines because they had wanted to take these along in their caravans.

In our first case study (van Dam et al., (2010) the participants were required to self-report their meter readings, resulting in a high margin of error. It appeared that many participants had omitted digits, reversed the readings of day and night tariffs, or had reported readings that were a factor 100 or more than their previous readings. All this seems to suggest that the conception of energy is low amongst households.

## **2.4 The baseline check**

The baseline energy consumption is the amount of electricity a household consumes when none of the appliances are in (active) use. In most homes, electricity is consumed 24/7, for instance to keep the ventilation system and refrigerator going and to power the products that are in standby mode. During the case studies it appeared that the most popular HEMS routine is to check the electricity consumption before going to bed, as a way of affirming that the house is at its baseline energy consumption (i.e. in its ‘sleep mode’). This ritual was also noted in Kidd and Williams (2008). As one participant said: “there were times sitting in bed, turned the light out and then try to get the little light (on the Efergy monitor) to come on so we could read it in the dark – ‘yea, we’ve dropped! Night night, darling!” In our third case study, a participant indicated he would like a small screen so he could check and turn off appliances that had accidentally been left on while he was already in bed.

## **2.5 Beware of the boomerang effect**

HEMS should strive to make the consequences of the users’ actions clear. Plain facts on energy consumption bring knowledge but not understanding. Likewise, “averages” in energy consumption are a poor guide. Energy consumption varies significantly throughout the week, making an average daily consumption rather useless. As Darby (Darby, 2010) noted, extrapolating daily or weekly consumption to expected monthly or yearly consumption can lead to highly erratic estimates, which users can find hard to trust.

Additionally, users need a reference for total energy consumption but this needs to be tailored to different household types. Several participants in our case studies indicated that they did not know if the energy consumption displayed on their HEMS was abnormal or not.

It might therefore be useful to give households a norm to compare themselves to. However, Schulz et al., (2007) warn of the boomerang effect: the phenomenon where households increase their energy consumption, instead of decreasing it, because they are below the norm (the norm being the average neighbourhood energy consumption). Researchers disagree on how to prevent a boomerang effect from happening. Schulz et al., (2007) claim that given people normative as well as injunctive feedback (approving or disapproving certain behaviour) eliminated the boomerang effect. Ayres et al. (2009) however, did find the boomerang effect for low energy consumers in both their studies even though both descriptive as well as injunctive norms were used. This indicates that when using comparative feedback care should be given to preventing this effect. This can be done either by only giving high-energy consumers comparative feedback, thus creating tailored HEMS, or by setting different norms for different use groups and adjusting the norms through time.

## **2.6 How to manage the energy manager**

Energy managers can help people control if and when appliances use energy, for instance through scheduled timers. But there is too little knowledge in most households of the workings of all appliances to successfully use a HEMS that manages energy consumption. This lack of knowledge can lead to situations in which appliances are switched off that shouldn't be (for safety reasons or the negative effects on energy consumption) or appliances are left on unnecessarily. Examples from the case studies are two participants who put a timer on their refrigerator to make it turn off during the night, and a participant who left his modem on because he thought it would be impossible to start it up again without receiving a new IP address. The difficulty for many people is not turning on their devices, the problem is knowing (or forgetting) when and how to turn them off. Designers should be aware of this when designing household appliances and consumer electronics.

## **3 Implementation of HEMS**

The introduction of HEMS in household requires careful preparation, both concerning the design of HEMS as well as in the way they are introduced.

### **3.1 The challenge of existing housing**

While most HEMS are intended to be implemented in existing houses, it is highly challenging to develop a HEMS that can be implemented in *all* existing households without having to adjust or replace the current meters or devices. This is typical of the challenge of making existing households more sustainable. It is difficult, if not impossible, to mass-implement a certain measure. Rather, batch jobs or tailored measures should be the norm.

### 3.2 Its my 'thing'

A HEMS is often the 'pet' tool of one person in the family.

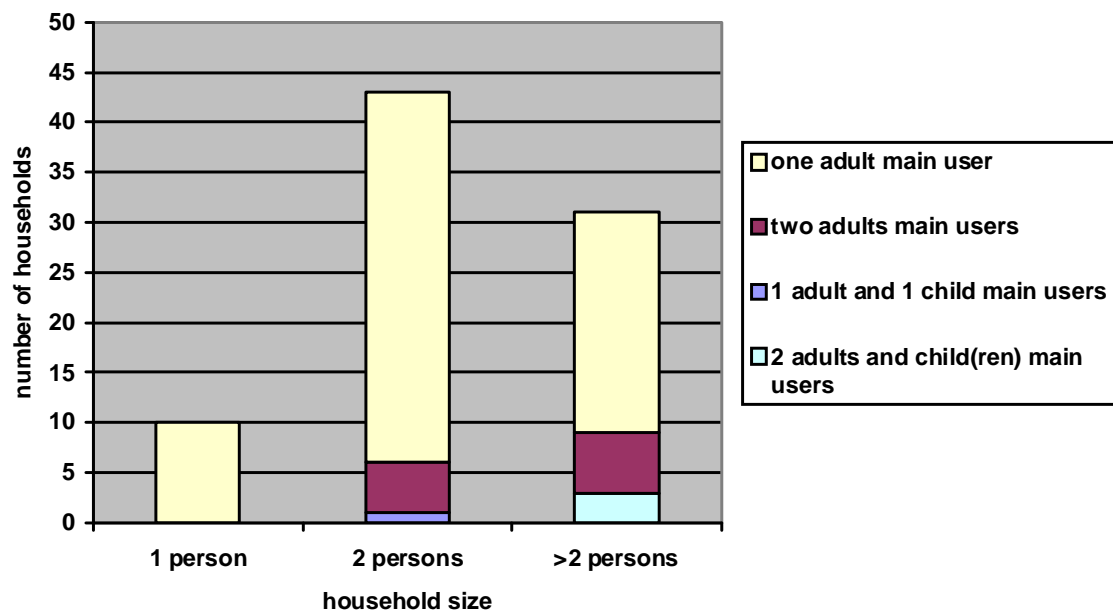


Figure 1 Number of main users per household after 15 months

The first case study (van Dam et al., 2010) showed there is often one main HEMS user. Figure 1 shows that the majority of households had one main user, and figure 2 shows that this user was generally male. An important note is that this case addressed *main* users, but that it is likely that other members of households also use the energy monitor to a lesser extent. It is plausible that different HEMS appeal to different genders, which would be interesting for further research. It could then also be addressed how to make HEMS more appealing to women.

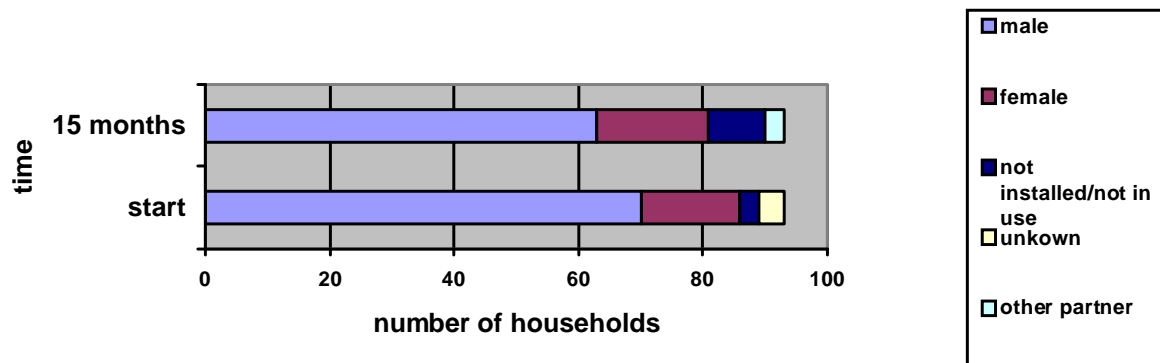


Figure 2 gender of (one of) the main user(s)

### 3.3 Sustainability 'freaks'

Often, one adult in a household holds sustainability dearest to his/her heart. This person is the family catalyst concerning sustainability. The tactics vary, but regularly this person will badger other members of the household concerning the length of their showers, their forgetfulness in turning off lights or appliances, etc. For a number of households it is not only about sustainability per se but in addition -or instead- cost reduction is an important motivator. A number of the sustainability advocates who tested a HEMS indicated that they feel better equipped to this task with the help of a HEMS. As one participant said: *"My children used to shower every other day. But nowadays they all –except for me- shower every day. And sometimes they take long showers, and then the door is locked, so then I have to knock on the door once in a while. Like: 'hurry up a bit!'. How much that costs, I don't know exactly. But now I could quickly run down the stairs to look. And then I can also show it..."*. Another female participant said she hoped her husband would use it and change.

Whether the main user of the HEMS in households is the same person as the sustainability advocate is an interesting question for further research. Outside these case studies mention has also been made that users apply a HEMS as 'badgering tool': *"I mean some nights I can come home from work and the whole house is lit up like Blackpool Tower - the computer's on, the telly is on, the radio's on in here and there's nobody in the house! That used to drive me up the wall but they are now starting to think. I've been badgering them and I've been flashing that meter in their faces!"* (Kidd and Williams, 2008)

A HEMS should therefore be able to serve as tool in helping its user identifying, proving, and altering a specific behaviour of another member of household.

### **3.4 Process of change**

Some participants in the case studies indicated that acquiring a HEMS is part of a longer process of change in which they are 'growing' towards sustainability. Woodruff et al., (2008) found that for the 35 homes they interviewed sustainability was often a progressive development over many years. This aspect needs to be examined in more detail, in order to understand the role HEMS can play in aiding people in this change process.

### **3.5 Short term effects**

A HEMS in itself often does not create a lasting behaviour change. The overall effects in mid to long term case studies are indecisive (van Houwelingen and van Raaij, 1989, Mountain, 2006) or show a decrease in savings (van Dam et al., 2010). This indicates that in most cases the effects of an energy monitor are only short lived. It is therefore questionable whether a traditional sales model for HEMS is the way to go. A HEMS is not a useful instrument for all households and not all households manage to reduce energy consumption. When marketing HEMS as effective and useable for all households, the sum total of HEMS' effectiveness will decrease. Careful consideration is needed as to which user groups will be targeted.

### **3.6 Break even point**

Consideration should be given to the overall life cycle impact of HEMS and not only to the savings that can be achieved. In other words, a trade-off needs to be made between the energy needed for production, use and disposal of HEMS versus the amount of energy saved by using it. When the savings achieved through HEMS are only sustained for a short period, it is hard to break even with the amount of energy invested. A life cycle assessment (LCA) can be a useful tool here. In light of the questionable long-term effects of HEMS it can be argued that a HEMS should not be developed as a stand-alone product but should be integrated in existing products instead. Care should however be taken that the simplicity and accessibility of the feedback is maintained.

## **Conclusion**

As stated in the introduction, the aim of this paper was to present a number of insights useful to the design and implementation of HEMS. As the case studies are still ongoing, these insights are in development. They are the first step, and during the coming period more insights will be gathered with the intent to translate these into guidelines for the development and implementation of successful HEMS and other energy saving interventions in the home.



These insights give a first glimpse of what is yet to come. Hopefully they can be improved and fine-tuned through an open discussion.

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