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Household appropriation of electricity monitors

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Abstract

In the perspective of smart grids, 'smart' electricity metres are distributed in European households. When households possess an immediate feedback on their consumption, it is usually stated that they can save between 5 and 15% of their electricity. How households learn to reduce their consumption is hardly ever addressed. In order to know whether 15% saving is a limit or not, it is necessary to understand what people do and learn with the use of an electricity monitor. This question is related to the way the societal energy transition could be achieved. Electricity is invisible, but it is produced, transported and consumed through material devices. This paper explores the dimension of material culture in household energy consumption through the introduction of electricity monitors in different types of households. Through a social experiment, we investigate both how households appropriate an electricity monitor and what they learn when using it. The paper addresses the question of appropriation of such monitors and how it is related to different dimensions: comfort, values, knowledge, skills, material culture. On the basis of an original protocol that intends to interfere as little as possible with users, we installed different metres in 21 Belgian households (including low-income households) and collected data on energy consumption, material culture (appliances, heating system, etc.), different representations of energy, energy-using practices and the effects induced by the introduction of the monitor. We have observed that the metre can change electricity perception, but that only households already interested or involved in energy savings are willing to use and learn with the monitor. We suggest that these devices should accompany a deeper transformation of the 'culture of energy', but they have to become much 'smarter' if their aim is to support more sustainable energy consumption patterns.

Introduction

Real-time displays of electricity consumption (simply referred to as 'smart metres' or electricity monitors) are now marketed towards households. These monitors show either the global electricity consumption of a household or the individual consumption of an appliance. They are announced as helping to 'reduce electricity bills and live in a greener house'. Yet that remains a point of dispute as some articles claim otherwise (Marvin *et al*., 1999; The Climate Group, 2008; Martiskainen and Ellis, 2011). The smart metre is not a stabilized technological object as it is yet a topic of controversy. There are at least two ways of looking at the 'smart metre'. Firstly, it is seen as part of the envisioned smart grids. Secondly, it is conceived as an instantaneous feedback device providing useful information to consumers. Let us notice that these two perspectives do not exclude each other.

In the first case, smart metres are electricity metres with advanced functions. They can detail consumption more precisely than a conventional metre and can communicate via some network with the energy provider or the grid manager. Saving energy is then delegated to the energy provider who is able to establish variable tariffs and is even able to switch off and on some equipment (washing machines, dryer, refrigerators) to 'shave' peak demand in electricity. The idea of variable tariffs, namely electricity cost that could vary according to the time of delivery, requires well-educated consumers who would be able to follow the electricity cost variation and change their behaviours accordingly.

In the second case, the 'smart metre' is a real-time display that is supposed to help users monitor electricity consumption of appliances and identify the most expensive uses of electricity. These monitors are of two types. Simple counters to plug into the socket of an appliance to measure its electricity consumption and metres connected to the main incoming power of a house/flat to measure its total electricity consumption. These devices are more and more common, and they are made available to the large public in shops or through the Internet. They are announced as tools for reducing energy bills and promoting greener behaviour (COM, 2006). The argument goes as follows: by providing real time and more

detailed information about energy practices, the monitors should help in motivating consumers to reduce demand as they see how much energy they are using – and money they are spending on energy. The energy infrastructure has been built to make energy consumption invisible as those actions previously made by the human body are increasingly being delegated to machines.

The idea of a metre is to add a device to the infrastructure that could make electricity use visible. The argument is supported by studies on consumption feedback that show that providing real-time feedback regarding electricity consumption can result in energy savings typically between 5 and 15%, depending on a number of feedback characteristics (Darby, 2006a; Fischer, 2008). However, the issue of how households are recruited for the experiments and the question of what they learn is hardly addressed. Furthermore, the overall experimental conditions are diverse and not always mentioned (e.g. duration of the experiment, design of the feedback, help and advice from the researchers, price of the monitor).

In this paper, we aim at understanding what consumers can learn when they use an electricity monitor and how they react to the introduction of a new appliance, which is supposed to change their behaviours. The next section outlines the supposed importance of electricity monitors in transforming the 'culture of energy'. Section 3 describes the theoretical background, which informs the research questions. The original interdisciplinary methodology is detailed in section 4. Section 5 presents the results of the experiment in categorizing households according to their electricity consumption behaviour. Finally, section 6 draws some conclusions about the hypothetical role that monitors could play in changing energy-related practices.

The role of electricity monitors in the culture of energy

In order to understand how electricity monitors could help households to reduce their consumption, we summarize some elements that shape the current context of energy consumption:

- Household electricity consumption is steadily increasing in Europe (increase of 21% between 1990 and 2007 in the EU-27). This increase is explained by several trends: new appliances, households are increasingly equipped, more households. Households own more and more appliances and the share of small appliances in the total electricity consumption is now higher than 50%. As the average household size drops, the number of households rises, along with the number of appliances used.
- The share of electricity in the whole household energy budget is increasing, because energy consumption for heating is either stabilizing or decreasing. That means that electricity consumption is becoming a more urgent issue.
- Energy networks are built to add new activities and appliances easily. The general default setting of energy networks is conceived in such a manner that it is easier to consume more than it is to save.
- Consumption and schedule organization are increasingly individualized, depending on personal appliances.
- Most people do not know their energy consumption.
- Households do not consume energy (Wilhite *et al*., 1996): integrated in daily practices the different appliances provide useful services, and energy comes about only with the (monthly or yearly) bill. Daily practices are routinized activities embedded in stabilized technology and infrastructure. The action of consumption and decisions about it has been delegated mostly to objects (thermostats, programmes, etc.).
- Households' practices are particularly difficult to analyse. Conflict or controversies in households are not public. Ethnographic methodologies have to be developed in order to understand what is going on in these private spaces.

These elements of the current 'culture of energy' help to explain that efficiency gains borne by new appliances are more than absorbed by the proliferation of new energy-related practices. This culture rests on the idea of energy that is invisible, abundant and cheap, and used by consumers who are passive and ignorant. The transition towards a new culture, or a so-called socio-technical regime, requires change in perception towards energy. Users need to be conscious that energy is precious, and they are able to transform their practices accordingly. The development of an advanced metering infrastructure and feedback technologies is then presented as the opportunity to empower users (in our case, households, users in the residential sector) to reshape their energy using practices. Yet the question remains how an electricity monitor could activate the transition towards new, more sustainable, practices.

The ability to provide electricity feedback is the main rationale behind the drive for smart metres. They are expected to lead to electricity savings, because they allow consumers to monitor their energy use in real time rather than looking at their electricity bill months later (Abrahamse *et al*., 2005; Jensen, 2008; Lockton *et al*., 2008). Besides companies and the State, households declare their interest for these devices. For instance, we have observed in focus groups and in a quantitative survey that, when asked, people are rather interested in getting adapted information about their energy consumption (Wallenborn *et al*., 2006). In our survey in 2005, we observed that 69% of Belgian people state that they would pay attention to energy consumption if their appliances displayed this consumption. So, at first view, the different actors are interested in energy monitors. However the results of our study and those of Hargreaves *et al*. (2010) – published during the writing of this paper – show that an energy monitor could be a falsely good idea. In order to understand this, we need to introduce the theoretical framework that has informed our study.

Theoretical perspectives on real-time monitor

Studies on sustainable consumption usually depart from the rational choice model based on classical economic theory. Many studies have shown that rationality of people in daily life routines is plural and not fixed. Generally speaking, people are not guided by one single energy use rationale or one single energy-saving rationale. Rather, their rationales tend to depend on the practice. People make choices and adopt certain behaviours, compartmentalized by practices (Bartiaux, 2008) in line with a set of criteria and constraints in which saving energy or money is often a less important factor than other personal criteria, as comfort, cleanliness or convenience (Shove, 2003). The European directive on energy services generally rests upon the rational choice model and defines the user as well-informed and reacting to signals as prices (Prignot and Wallenborn, 2009). This kind of behaviourism precludes some important questions to be asked such as in the

learning process involved in any experiment (Darby, 2006b). In this paper, we focus then on how households appropriate a new object and what they learn with it.

We rely on different theoretical perspectives and other empirical findings to frame our research questions. Concepts at the crossroads of Science Technology Society theory and practice theory approaches have been found particularly useful in interpreting and explaining our results. Theories of design have also been prompted. From this perspective, the issue is to know how an object can help to transform a culture, how an electricity monitor is incorporated in current practices and whether practices are changed.

Studies about the 'domestication' of objects emphasize the role of users in the appropriation and underline the fact that it is often a very active process (Akrich, 1995; Pantzar, 1997; Aune, 2007). Technologies are not just adopted and accepted; they are actively integrated into households' dynamics. This is mostly visible with new technologies that modify a practice and not just replace an older appliance for the same use. For example, the introduction of a computer and the changes it makes in a household is certainly visible when the computer is new or when a major revolution came, like the introduction of the Internet. Just replacing a computer by another one is not likely to change the practice except if the old one is used by the children for new purposes. In these cases, computers may change the way people interact, associate with other people, inform themselves, buy things and so on. The laundry routine and the introduction of a washing machine is described by Kaufmann (1998) as modifying or being part of the negotiations taking part in a couple.

The 'appropriation' concept is used to describe how users integrate the objects in their own lives, households or network. Users integrate objects into an existing set of other objects, skills and meanings This suggests that humans are affected by the objects they integrate into their daily lives. The appropriation process is a matter of reciprocity: humans influence objects, and objects influence humans. An object can change the time schedule of the family, it can change the way users interact and it can modify their symbolic network. The introduction of new technologies may change the 'clocking' of households, the rhythms and routines of households that fit in a more public organization of time (Shove, 2003). Hygiene and wealth are also organized internally with objects, but in regard also of what is considered as being socially accepted (which is also mediated by objects). So objects play a role at both the personal and societal levels. There are different steps in the life of a product on a market. It can go from a very specialized niche of users to a mass market. It can turn from a toy to an indispensable tool (cellphones, televisions). It can go the other way around, from a useful tool used for professional purposes to a widely used tool used for entertainment (e.g. phones) (Pantzar, 1997). The pathway is not given and depends on the objects. When an object becomes 'normal', its acquisition no longer requires a justification.

As marketed electricity monitors are various with different characteristics and with a price amounting to hundreds of Euros, we are still confronted to a market niche. And protocols of smart metering experiments can be very different: immediate or delayed feedback, with variations in the kind of information received, the kind of appliance inspected and the length of the experiment. The interaction between smart metering and other forms of information at this stage is rather unclear. Some studies conclude that information alone is enough for a behavioural change; others conclude that information does not add to the economies made with smart metres. Two important effects are put forward: the drawback effect and the Hawthorne effect. The drawback effect is defined as 'the phenomenon in which newness of a change causes people to react, but then that reaction diminishes as the newness wears off' (Wilhite and Ling, 1995). The Hawthorne effect is the fact that people react differently when they know they are being watched. Those two effects can interact with each other. Nevertheless, academic studies give an idea of the maximum of reduction that could be reached. Most of the literature concludes that it is possible to reduce the energy consumption, but the numbers and figures vary greatly (Darby, 2006a).

In all these studies, it is, however, never clear how participants have been recruited. These studies are usually done with highly motivated people, who tend to be better educated and have higher income than average (Abrahamse *et al*., 2005). Liikkanen (2009) has developed interesting ideas about how to design a smart monitor, but his experiments were done with 'extreme users', namely people willing to use an electricity metre and ready to learn from it. That is, typical of the results we have about the use of an electricity monitor. In order to get around this problem, we have contacted households with various degrees of interests in energy and developed an original protocol to grasp what households learn with an electricity monitor.

An original methodology

The introduction on the market of cheap electricity consumption displays allowed the launch of a survey on the use of these 'smart' metres. In order to understand how appliances and technology could be better appropriated in the perspective of more sustainable patterns of energy use, we organized a survey on the use of smart metres in households. For that purpose, we have developed an original protocol for the realization of the survey of 21 Belgian households, which combines through its different steps (described thereafter) the competences of our interdisciplinary team (engineer, psycho-sociologist, economist, philosopher, designer). By installing 'real-time' metres in households (including low-income households), we collected data on energy consumption, material culture (appliances, heating system, etc.), representations of energy, energy-using practices and the effects induced by the introduction of the metre.

The choice of the metres

Due to technical constraints the choice was restricted among a few of the metres that are readily available on the market. These metres were found to be not very user-friendly nor technically irreproachable. In fact, their precision is not always sufficient, and they are often impossible to be installed. Furthermore, once installed, we observed that they are not well designed as they provide only figures in kilowatt and kilowatt-hour or Euros. In order to obtain graphics and analyse the data one needs to download the data and install a software, which has proven to be not very user-friendly. The metres have two main parts: the metering device, placed at the main incoming cable, and the display, which is mobile.

Recruiting the households

We paid attention to include very different households' profiles in our sample. As reviews of work by Darby (2006a) and Fischer (2008) show, studies on energy feedback are usually not clear about which households are recruited. As we wanted to escape from this pitfall, we have paid attention to recruit households through different channels.

We did not arrange a statistical sampling of households (due to a lack of resources), but we paid attention to have different profiles of households:

- households already involved in energy reduction (people working in a sustainable development context, for example, or having already participated to energy reduction campaign);
- households already aware of their electric consumption and interested in reducing consumption for different reasons (not only environmental ones), recruited through a electricity provider newsletter;
- low-income households, recruited through social housing associations (unfortunately, only one of these households completed the different phases of the survey, due to cultural and social difficulties);
- households not at all interested in their energy consumption (these are people we selected for the survey but they would not have asked for anything to control their energy consumption).

Installing the monitors

At the first step of the survey, an engineer, who presents himself in these terms, installs the measuring equipment and gives a brief explanation of the monitor to the household. The user's manual is left, and householders are invited to play with the power metre display options. It is also suggested that they try to reach a 'consumption zero level', i.e. stopping the use of electricity completely by switching off all their appliances. Households are also provided with a questionnaire on the possession and use of electrical appliances as well as on other data about the heating system and the home insulation, and they are asked to complete it at their convenient time during the weeks of the measures. Households were asked to note the most important facts occurring during the period of the measures (as holidays, parties, etc.). The metre is left in the households for 2–4 weeks.

After this period of time, the engineer comes back and downloads the data, displays graphics, decrypts and discusses with the household their electricity consumption.

Discussing experiences and perceptions around the smart metre and electricity consumption

In 3–6 weeks, after the engineer has discussed the consumption data with the household, an in-depth interview was led by a psycho-sociologist. Based on the collected data (consumption + questionnaire on appliances), the researcher stayed around 2 h in the household in order to discuss the way the household members perceive and understand their consumption of energy and to analyse the experience with the monitor (in particular, what they have learned and which practices have changed).

Findings of the social experiment

In order to try to synthesize the huge amount of collected data, we have compared the consumption of each household with the average consumption of a rational use of energy (RUE) household. According to this comparison, households are grouped as in Fig. 1: consuming more than the average (grey), normal consumer (black), RUE (black and white), 'super' RUE (white). We observe that 'super RUE households' are over-represented in our sample: we will see that this is related to a pre-existing interest in the monitor.

Through the presented protocol, we have gathered a huge amount of data on the material culture of these 21 households. Table 1 summarizes the main results of the survey. We organize the results according to the following dimensions:

- Perception change. This dimension points to the fact that the perception of electricity consumption has been changed or not after the introduction of the metre.
- Behaviour change. On the basis of the in-depth interview, we establish whether some behaviours have changed after the introduction of the electricity metre.
- Self-declared thriftiness. Do members of the household consider themselves to be thrifty?
- Observed wasteful behaviours. This dimension indicates that households declare to have wasteful behaviours related to energy consumptions (through in-depth interviews).
- RUE comparison. This dimension indicates the level of energy consumption, according to a standard RUE household: high, normal, RUE, super RUE (cf. Fig. 1).
- Energy interest. Through the recruitment channel, we can label households in the following categories: involved (the household has already taken part to other energy experiments), interested (it has been recruited through mails), not interested (it has been recruited through individual contacts), low income (it has been contacted through social services that manage social housing).

Before discussing the results presented in the table and interpreted through the interviews, we should recall that this methodology is qualitative and that no quantitative conclusion can be drawn from it. For instance, a side effect of our interdisciplinary protocol is the manifest discrepancies between the statements made by households in written questionnaire administrated by the engineer and the observations made by the psycho-sociologist. For instance, some households wrote that they hardly do any 90°C washing cycles, while in reality it is a common practice. This gap between declarations and practices is well known but indicates how much quantitative surveys on household consumption should be treated with caution. In the rest of this section, we present the main results and point to several striking correlations.

First of all, while perception of electricity has changed in most of the cases, behaviour change has not followed. Many users have learned through the electricity monitors that heating (water, rooms, oven) consumes much electricity. In some cases, it has been possible to track down 'bizarre' nightly consumptions that resulted from water heaters without clock regulation.

After the utilization of the monitor, five households state that they have changed (or they are going to change) their behaviour towards the use of electric appliances during the survey, at least for one or more of the appliances, they found out to be energy intensive. These households are all households, which do not show any

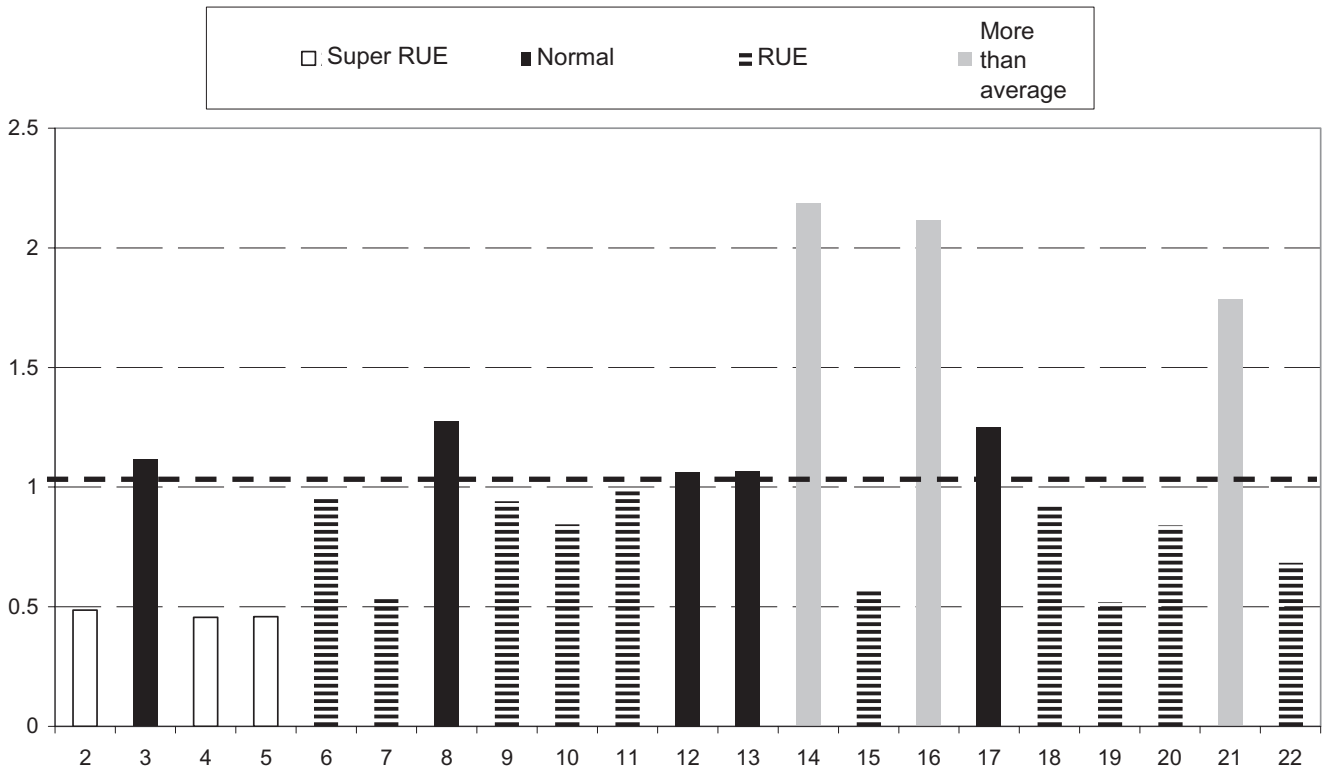

Figure 1 Electricity consumption of the surveyed households with respect to a rational use of energy (RUE) household.

Table 1 Summary of the main results

	Perception change	Behaviour change	Self-declared thrifty	Observed wasteful behaviours	RUE comparison	Energy interest
1	Yes	Yes	Yes	No	RUE	Interested
2	Yes	Yes	Yes	No	Super RUE	Not interested
3	Yes	No	±	Yes	Normal	Interested
4	No	No	Yes	No	Super RUE	Involved
5	Yes	No	Yes	±	Super RUE	Involved
6	Yes	No	±	Yes	RUE	Interested
7	Yes	Yes	Yes	No	Super RUE	Involved
8	Yes	No	Yes	Yes	Normal	Not interested
9	Yes	No	±	No	Normal	Not interested
10	Yes	No	Yes	No	Super RUE	Involved
11	No	No	±	Yes	Super RUE	Interested
12	Yes	No	±	±	High	Interested
13	No	No	±	±	High	Interested
14	Yes	No	No	Yes	High	Not interested
15	Yes	No	±	Yes	Normal	Interested
16	No	No	No	Yes	RUE	Low income
17	Yes	Yes	±	No	Super RUE	Involved
18	Yes	No	Yes	No	RUE	Involved
19	Yes	Yes	Yes	No	Super RUE	Interested
20	Yes	No	Yes	No	RUE	Involved
21	No	No	Yes	Yes	High	Not interested

RUE, rational use of energy.

sign of wasteful behaviour during the interview conducted at the end of the survey and are RUE or even super RUE.

Among the eight households showing wasteful behaviour for one or more of the appliances from their interviews, no one expressed the intention of changes in behaviour, even if six of them were said to be attentive to energy saving. Among these eight households, five acknowledge their consumption patterns and are aware of being above or in the consumption average. Nevertheless, they do not want to change their behaviours causing these consumption patterns. The other three households did not acknowledge their consumption patterns and are the most energy-intensive uses.

It is interesting to note the reasons provided by the five households who do not want to change their behaviours even if they recognize their relatively high consumption with the monitor. The change in the behaviour could cause a conflict within the household as some wasteful behaviours are associated with the good perception of a role in the household (washing clothes at 90°C is associated with being a 'caring mother'). When a potential conflict can arise between a couple in areas such as the temperature set for the washing machine or for heating, even when one partner has obvious technical skills, this partner prefers to remain silent in order not to create a conflict. Each member of such a couple has his or her own field of activity that consumes energy, and other members cannot interfere with it.

Another, paradoxical, reason that prevents 'behaviour change' is the self-esteem of the user about technical skills. The user of one of the appliances has, or thinks to have, the technical knowledge enabling him (or her) to justify choices and consumption patterns. In other cases, the (over)consumption of energy in a particular practice is associated with activities or services that provide 'pleasure'. In such circumstances, the consumer may not consider reducing these consumptions because of the preference to offset them with savings in other areas. These people will eventually be more tempted to buy more efficient appliances than to change behaviour.

Among households who do not want to change their behaviour, three reported not having acknowledged any trouble in their mode of consumption from the monitor experience review. We can explain that because either they do not have the skills to understand recommendations, they did not, as they said, discover anything they already knew or while seeing their consumption patterns and the peaks in consumption, they consider that their consumption is normal.

The five households who declare themselves to be ready to change their behaviours after the survey are motivated by a specific perception of the environment. They value ecology in a philosophical or political sense more than for economic reason. These households who can appropriate the metre are in fact already well informed towards energy consumption.

Overall, we found that current electricity displays are not well designed. For example, they only provide figures in kilowatt-hour or Euros. Graphic representations are more useful for households to track down unsuspected consumption but are not easily understood without the explanation of an expert. We have also noticed counterproductive effects when users realize that some appliances consume little and hence conclude they can use the device more. Because absolute consumption is often meaningless for households, they require comparisons in order to know whether they are on the right track.

Finally, we have observed a loose link between the number of appliances possessed by a household and its global electricity consumption. This relation is stronger in the case of lamps: high-energy households have a larger number of lamps than the average. Beyond the issue of behaviour and use, this indicates the importance of material aspects in energy consumption.

Conclusions

The growth of electricity consumption is going to become both a social and environmental problem in developed countries. Many sociological studies have shown that household practices are shaped through a diversity of factors and processes. It is then normal to note that the idea of making energy visible is refracted through the diversity of practices occurring in households. Electricity materializes (or not) in a pre-existing fabric of habits and meanings. The process of appropriation of the monitor depends on a range of factors, upon which the meaning given to energy saving seems prominent.

Cost of the energy monitors that would be imposed on a household has begun to fuel debates in France and in Belgium. At the moment, most of the experiments are made with free or cost-reduced monitors (and so we did). It is therefore not clear to know what price could be paid by households for an unclear service. The privacy of the data is also a hot topic. It is therefore crucial to understand better what could be the positive role played by the introduction of these new devices.

Most of the results of this study are in line with Hargreaves *et al*. (2010).[1] For instance, men are generally more interested in the device than women. All households declare to have learned something (hidden consumption), but some of them also state that it is not going to change their behaviour. The introduction of an energy monitor can trigger conflicts within households, and the display can be discarded to pacify relationships. We have also noted that people have difficulty interpreting figures in kilowatt-hour, and that the conversion in Euros does not look impressive (a household can only save a few Euros by year for a given change). There are indeed many debates about the kind of display that would be useful for households (Pierce *et al*., 2010), about which data to exhibit and how to present them. The place in the household of the display is also an issue: should it be fixed in the living room or should it be mobile?

When monitors are not integrated to pre-existing practices, the metre is readily absorbed in the daily background as any other new appliance. The presentation of real-time electricity consumption is not handy, and sudden peaks are not easy to interpret. Notwithstanding reservation about the design of the metre (not easy to be installed and to be read, need literate users), we think that such a metre, to be efficient, should be integrated into an existing appliance to get a chance to be used. The data provided by the metre could be carried to the user through Internet or through the mobile phone, for instance, so that this information would arise in pre-existing practices. Furthermore, for some kinds of households, a follow-up of the consumption should be organized. We therefore suggest that users should be involved in the design process, and this design should allow some room for different kinds of users.

[1]The discrepancies with this study could be explained by a different recruitment scheme. Their sample is described as 'early adopters'.

Our results are not statistically significant, but they give a good indication on (1) which households are ready today to use an electricity monitor and (2) how to improve the monitor and what surrounds it. We have observed that the monitor can change electricity perception, but that only households already interested or involved in energy savings are willing to use and learn with the monitor. We conclude that the monitor can be integrated into existing practices, but they do not trigger new practices by themselves. In other words, information works only with households already informed or willing to understand the information provided. This observation was already made in focus groups where we noticed that people who do not feel informed enough about an issue are also the ones not searching for information, whereas people actively looking for information that interests them find it not difficult to get it. Searching for information is therefore wholly part of a given practice, for it is related to meaningful activities performed by households. How information is integrated into practices remains, however, an open question.

Could the diffusion of the electricity monitor be seen as similar to the diffusion of other technological innovations (e.g. PC, mobile phones)? As the service provided by the device is quite peculiar (electricity consumption and nothing else), the question is how to interest people in the issue of energy use. The Internet has been generalized because it has offered more and more services and entertainment. By contrast, the energy monitor concerns only one (important) aspect. At present, it is added to existing appliances. A probable future of these monitors is to be integrated into existing devices such as PC or mobile phones. In conclusion, we believe that if we want to empower electricity users, we have to invent other ways of making energy precious than making it visible through a small monitor, even though such a device can help well-educated people develop awareness about their electricity uses.

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