Emerging e-Practices, Information Flows and the Home: A Sociological Research Agenda on Smart Energy Systems

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Abstract This chapter examines the emergence and development of smart grids from a sociological perspective. In particular we draw on 'social practice theory' to understand the dynamics of domestic energy consumption and production in emerging smart energy configurations. There are two focal points in the analysis. First, we will concentrate on a specific type of social practices, so called 'e-practices'. This is a term that we coin to refer to all those practices in and around the home that involve the consumption, conservation, monitoring, generation and storage of energy. Second, we incorporate 'information flows' as a key element in our understanding of the emergence of new e-practices. Although the term "smart" has been defined in various ways, a common denominator is that the generation, handling and use of data, information and knowledge is part of what makes a system smart. After introducing both concepts, we outline a conceptual framework around e-practices and information flows that can guide social scientific research on smart energy systems. We also illustrate how this framework can be put to use empirically, based on data that have been gathered in the Netherlands. The chapter is concluded with a research agenda that outlines theoretical and methodological challenges for future smart grid research.

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1 Introduction

The remarkable and widespread diffusion of the adjective "smart" to energy technologies has led to confusion and debate among utility managers, academics and policy makers about technological development and behaviour change, about autonomy and privacy concerns, and about the objective of smartness (do systems, meters and devices become smart, or their users, managers or regulators?). This chapter aims to shed some light on smart energy systems from a sociological perspective. In doing so, it draws upon conceptual frameworks being developed in the social sciences and on ongoing empirical research in the Netherlands.

Our understanding of the uptake of "smart" systems is based on Social Practices Theory. On the one hand, this theory deviates from many engineering perspectives on smart grids in that it considers social and material worlds/systems as inextricably entwined. On the other hand, it also deviates from behavioural approaches in (social) psychology and economics that concentrate on the minds and/or (trans) actions of individuals. Instead, a social practice approach promotes an understanding of reality in which thoughts and actions are structured by the socio-material contexts in which they take place.

This chapter is built up as follows. In Sect. 2 we start with an elaboration of what Social Practice Theory has to offer for analysing the emergence and uptake of smart energy systems in and around the home. To this discussion we add insights of 'informational governance' to construct an analytical framework around emerging e-practices and information flows. Section 3 presents selected findings of ongoing research in this field to show how this conceptual framework can be set to work. To conclude, a research agenda on e-practices in smart grid configurations is presented in Sect. 4. The agenda reflects research in progress as well as research directions for the future.

2 Social Practice Theory and Smart Energy Systems

Since about a decade, Social Practice Theory (Giddens 1984; Schatzki 2002; Shove 2003; Spaargaren 2003) has become a prominent theoretical perspective in social scientific research of domestic energy consumption. It presents a valuable addition to our understanding of domestic consumption, an understanding that was so far dominated by social psychological theories of Attitudes and Behaviour (Fishbein and Ajzen 1975), Planned Behaviour (Organ et al. 2013), Normative Behaviour (Abrahamse and De Groot 2014) and Bounded Rationality (Simon 1955). Rather than focusing on individual attitudes, behaviour and choice as the main attributes of domestic consumption, Social Practice Theory directs attention to the shared, routinized and embedded nature of everyday consumption practices. Within this sociological view domestic routines and activities that involve energy use are pictured as much more complex than often suggested in the above mentioned literature or than often expected by policy makers and energy providers

(Gram-Hanssen 2010; Shove et al. 2012; Strengers 2012). In this section we will first elaborate on energy practices (or: e-practices), as a specific type of practices, and then touch upon some concepts that are relevant for analysing the dynamics of e-practices in and around the home.

2.1 Energy Practices

Social practices have been defined as "a routinized type of behaviour which consist of several elements, interconnected to one other: forms of bodily activities, forms of mental activities, things and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge" (Reckwitz 2002, p. 249). Practitioners draw upon their know-how, emotions, conjunctural (practice-specific) dispositions (Spaargaren and Oosterveer 2010) to perform mundane everyday activities. Besides, social practices produce and reproduce social rules and norms (Giddens 1984). For our analysis a specification of Reckwitz' definition of social practices is needed: connecting with "things and their use" should be understood as employing technology and information flows. People tap into information flows in their daily performances of practices, e.g. gardening is typically coordinated with weather forecasts, online shopping involves checking the bank account balance, while domestic energy management requires energy data from meters and displays. Social practices, including e-practices can thus be defined as routinized types of behaviour that result from conjunctural dispositions, and know-how of groups of individuals who draw upon specific objects, information flows, technologies and social rules and norms in order to (re) produce the practice.

With the help of Social Practice Theory it can be shown how every day behavioural routines of specified groups of energy-users emerge, stabilise, become reconfigured, and dissolve or fade away. Analysing the dynamics of social practices implies investigating the know-how of individuals that take part in a practice and the meanings they attribute to it, while taking into account the co-shaping roles of objects, technologies and infrastructures that are relevant for that practice. Individual norms, values and preferences are thus not considered in isolation, but as shaped in a context of practices that are shared with others and that co-produce new value-orientations of individuals. As such, a practice approach allows us to investigate in detail the dynamics of activities taking place in domestic and local settings, while not losing sight of the broader context of systems of energy provision (Spaargaren and van Vliet 2000; van Vliet 2012).

We propose to speak of "e-practices" when the routine behaviours refer to the production, distribution, storage, monitoring and use of domestic electricity in a domestic or decentralised setting. Studying the emergence of e-practices that comes along with the roll-out of smart energy systems in the Netherlands and Europe means that we are dealing with moving targets. We aim to investigate how this emergence takes shape. Will we indeed witness the emergence of an independent

set of e-practices as a consequence of enrolling citizen-consumers into smart energy systems? Or rather, do we expect to see changes in various existing domestic practices that involve the use of energy? As this is also very much an empirical question, we see emerging e-practices, for the time being, both as the birth of new practices (i.e. the monitoring of domestic energy flows, the utilisation of new smart meters and smart appliances) and as adaptations of existing practices (i.e. adapting the timing of laundry practices to moments of abundant solar energy supply).

2.2 *Dynamics of the Home*

Studies of domestic (energy) practices should take account of the immediate context in which they take place: that of a home. The boundaries of the home, and the personal lives that it harbours, are blurry and flexible, but the dynamics of e-practices in the domestic sphere constitute unique theoretical and empirical challenges regarding intervention and transformation (May 2011). Here we discuss various aspects of the home that are relevant to understanding the emergence of e-practices.

First of all, from a social practice perspective the home is to be understood as a means of association between practices—e.g. doing the laundry, showering, cooking and eating, or communicating—that fulfil specific domestic tasks (Gregson et al. 2007; Shove et al. 2012). These practices are performed by human agents who communicate about and make use of technological objects, machines, energy and information flows that connect them to wider technological infrastructures delivering energy, water, data, etcetera (Cowan 1983; Otnes 1988). We consider households as "hybrids of objects and people, which are implied in the (routine) performance of a series of interconnected practices reproduced in the domestic arena with the help of energy as a key resource" (Naus et al. 2014). Figure 1 depicts a number of domestic energy practices (in the circles) that are of special relevance when considering smart energy systems.

Besides consisting of interconnected practices, each household has its own "socio-technical configuration" and "moral economy", which condition the

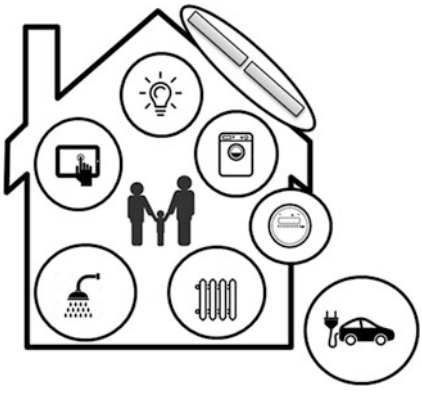

Fig. 1 Domestic energy practices (adapted from: Naus et al. 2014, p. 438)

performance of these practices. The socio-technical configuration points to the specific qualities of a household that emerge from several factors, most importantly the education level, age, gender, life phase and income level of its residents, as well as the technological infrastructures and devices present in the home (Gram-Hansen 2010). The concept of moral economy "recognises that different households, even if they are demographically and technically comparable, have different histories and social practices through which they have developed agreed norms and values, habits and routines which are normally unquestioned" (Hargreaves 2012). A moral economy is (implicitly) shared by the members of the household, naturalising and moralising a certain way of 'doing things' in the home. Hence, a moral economy ties together various e-practices on the basis of a 'regime' of norms, including norms regarding comfort, convenience, autonomy, control, privacy, sustainability.

Running a household also involves specific rhythms and sequences of events. Smart energy systems challenge existing rhythms of everyday life (Walker 2014). People organise their daily activities, balancing convenience and care, and spontaneity and stability, and end up creating "hotspots" (periods of mindful activity) and protected "coldspots" (when people relax) throughout the day and the week (Southerton 2003, 2006). As people go about their daily lives in and around the home, they continuously waver between routine and reflexive behaviour (Southerton 2012). Therefore, domestic energy consumption has always been more or less reflexively 'monitored' and 'timed'. Yet, with the emergence of smart energy systems the monitoring and timing of use are given new precedence. Therefore concepts of hotspots and coldspots can be usefully applied to assess the temporal dynamics (flexibility in particular) of new and existing energy practices.

Finally, interventions in the home often involve a process of "habituation" in which householders learn to work with new technologies and, at the same time, shape the functions of these technologies durably. The roll-out of smart grid technology constitutes an intervention into established domestic practices, introducing new technologies, engagements, emotions, knowledge and know-how. Such interventions can spark a habituation process in which households alternately reflect on their routines ("cultivation") and turn new conscious acts into new routines ("naturalisation") (Wilk 2009). From an environmental perspective, a habituation process is successful, when households abandon old carbon-intensive practices and are durably enrolled in new, more sustainable energy practices that are endorsed by the smart grid.

3 Information Flows in Smart Grid Configurations

Thus far we addressed the enrolment of households in (smart) energy systems through their practices. This section zooms in on the role of information as a key flow next to energy flows in smart energy systems. It builds up to a conceptual framework that connects information flows to energy practices.

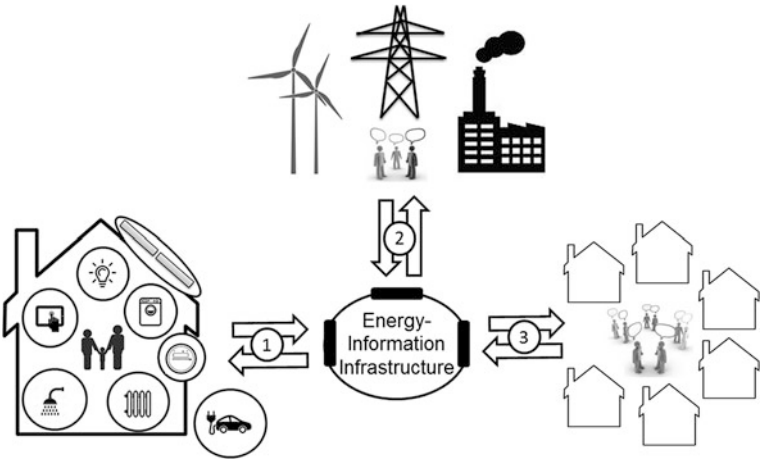

Fig. 2 Energy and information flows in the smart grid: *1* between household members, *2* between households and service providers, *3* between local and distant households (adapted from: Naus et al. 2014, p. 439)

Following Castells (1996) and scholars of informational governance (Mol 2008; Van den Burg 2006) we identify information flows as a key concept for analysing emerging e-practices in smart grids. The term 'information flows' is a sociological concept that refers to the exchange of diverse forms of data, information and knowledge (Mol 2008) between actors. Figure 2 discerns three flows of information that are relevant in a smart grid (Naus et al. 2014).

A first information flow is largely generated and used by residents within the context of the household. This is the information about energy use of devices, generated by generic meters or by specific meters that monitor energy demand in specific rooms or devices and at different times. The information is interpreted, shared and used in (daily) conversations among household members dealing with the timing and use of heating, cooling and lighting in domestic e-practices.

A second information flow pertains to the interactions between households and their energy service providers. Traditionally this is a one-way flow of information between utility companies and their clients, in the form of an annual energy bill that specifies energy consumption and payments. With the emergence of smart meters, and renewable electricity generation by consumers, these flows of information have become two-way, more frequent and more complex.

The third information flow relates to the interactions between households and other local and/or distant households. This is the case, for instance, when householders join a local energy cooperative, or when they become co-owner of a wind turbine or solar power plant. Also storage of locally generated electricity and the charging of electric vehicles may require information exchange between householders.

So, whereas the first category of information flows is largely contained within the private sphere of the home, the other two flows refer to information exchange with actors operating in the realm outside the household.

Our conceptual framework of a smart grid configuration now consists of three domains: (1) the household, as a set of interconnected (e-)practices; (2) energy service providers, including grid operators, electricity suppliers and regulators; and (3) groups of households, that can work together in various ways. In between these three categories there are energy and information flows that are operated and maintained in what is now called a smart infrastructure.

3.1 Information, Control and Privacy

All three information flows can have desirable as well as undesirable consequences. On the positive side, it has been suggested that smart meters put citizen-consumers in a better position to reduce the climate impact of their energy consumption (van Vliet 2002; Mol 2008; JRC 2011; Nyborg and Røpke 2011). Firstly, through real-time monitoring of domestic consumption, possibly down to the level of individual rooms and appliances, citizen-consumers acquire an increased understanding of possibilities to lower energy use. Secondly, based on the display of production information on smart meters (e.g. fluctuating tariffs, generation source, efficiency) citizen-consumers can make better informed choices between (sustainable) power options and energy suppliers (Darby 2010; Nye et al. 2008). So in this sense, smart meters enhance citizen-consumers' control over energy-related practices and facilitate the realisation of an 'ecological rationality' (cf. Mol et al. 2009).

However, on the negative side, the disclosure of detailed energy consumption data also implies a potentially undesirable opening-up of activities occurring inside the household; smart meters can reveal (intimate) rhythms of everyday life, like consumption behaviour, eating and sleeping routines and whereabouts (Cavoukian et al. 2010). In this way, daily practices and routines enacted in the private sphere 'behind the meter' are made 'visible' for energy suppliers as well as for other family members and neighbours (Van den Burg 2006; Mol 2008). These increased levels of transparency raise critical questions on the secondary use of information, and particularly on privacy (Cavoukian et al. 2010; Van Gerwen et al. 2010; JRC 2011). In this respect the large-scale 'roll out' of smart meters has been framed as introducing new forms of 'surveillance' (cf. Foucault 1995) and as the 'colonisation of the lifeworld' (cf. Habermas 1981) by energy systems, that citizen-consumers will tend to resist.

The deployment of smart grids and smart meters for environmental goals is therefore not self-evident; while new forms of information disclosure may facilitate the 'greening' of domestic energy consumption, this disclosure can also result in new forms of surveillance. As such, smart grids reconfigure existing power relations, and introduce new forms of control (Spaargaren 2003; Southerton et al. 2004).

4 Findings on Emerging e-Practices and Information Flows

Having presented the domains and concepts of sociological research on smart grid configurations, in this section we show how our framework can be utilised for empirical research. In doing this, we use findings from several studies that were conducted in the Netherlands. First, we present findings from a number of qualitative interviews with householders who participated in a one-year smart meter trial that was set up by a Dutch grid operator and a consumer organisation (Naus et al. 2014). Second, we present survey data on the involvement of householders in an energy cooperative (Naus et al. 2015; Sedee 2015).

The Netherlands provides a particularly interesting venue for research given the public and political debate on smart meter implementation as a result of concerns over consumer privacy (Hoenkamp et al. 2011), the widespread emergence of local energy cooperatives in recent years (Schwencke 2012), and the establishment of several 'experimental gardens' for the testing of smart grid technologies in real-life settings.

Rather than using all of the concepts that have been introduced in the previous section, we will limit the analysis to the interrelations between information flows and e-practices. In particular, it is shown how information flows interfere with and redefine social and power relations within the household, between households and energy providers, and between different households. This has consequences for whether and how e-practices emerge, develop and take shape.

4.1 Information Flows Within Households

During the first weeks after installation of energy displays, participants in the smart meter trial showed significant interest in energy monitoring. The new energy displays enabled them to make better informed decisions, since data on specific uses had become available. Interviewees reported a variety of changes in their consumption practices in terms of timing of use of appliances, the use of lights in the evening and replacement of inefficient appliances for more efficient ones. However, the practice of energy monitoring faded somewhat over time; after a few months it did not provide much new information and the monitoring practice became established as a more 'modest' routine in some cases, while in other cases it faded away all together. Yet, some of the measures that were taken during the time of more intensive monitoring lasted in the form of newly established routines. One of the interviewees developed a new routine of recharging electric devices:

> At this moment (2p.m.) all kinds of stuff is being charged. Until 3 pm, that's when I have to switch them off (…) You become a bit of a slave of your solar panels, so I have to restrain myself a bit. But I like it so much! Because now it is clean, and it is my own energy!

This example clearly shows that new rules have been established regarding the timing of recharging practices. Afters some time it was no longer necessary to check the energy meter for information, but the timed recharging remained as part of everyday life. Furthermore, the example shows that both the technical configuration and the emotions that came along with that played an important role in the process of re-routinization. In fact, it seems reasonable to assume that the new practice became established only because it involved energy that was produced by the interviewee's own solar panels.

Furthermore, the trial showed that the emergence of new monitoring practices depends not only on the particular form in which energy data can be accessed (e.g. through a smart display or through a monthly email), but also on the creative selection and interpretation of the information by the householders. Some interviewees used smart meter information to engage family members in energy saving practices. In other cases monitoring rather introduced a new mode of surveillance. In the following example data on electricity demand are used by a parent to question an adolescent's behaviour:

> This [electricity peak] is, I think, my son, who returns home in the evening and turns on the microwave. (…) We have asked him: what are you doing here? But he is not interested and not very eager to think along.

Thus, rather than having an effect on energy use, energy monitoring (re)produced a power relation between parent and child. It shows that monitoring is not always geared towards energy saving, but can have multiple uses and sometimes unexpected outcomes (Naus et al. 2014).

4.2 Information Flows Between Households and Providers

In traditional relations between energy utilities and customers, information flows are generated from annual meter readings at home, resulting in an annual energy bill reflecting and justifying the kilowatt hours delivered and consumed. In settings where smart meters have been installed, or where renewable energy is generated on a local or household level, information flows can multiply and become multi-directional. Our interviews with householders and institutional actors revealed that smart meters and smart grids open up new opportunities for information exchange between households and energy service providers. Providers speak of business opportunities in providing their clients with energy saving or time-shifting advices based on more fine-grained monitoring data. In fact, one of the energy providers foresees a wholesale shift in the role of energy providers from energy supply to the provisioning of energy saving services:

> There is more money to be earned with giving pro-active advice and helping consumers in their efforts to save energy.

If the energy market indeed develops in this direction, then increasingly household practices would become connected to external advices and demands. While this may foster sustainable energy use and reduce household energy bills, there we also interviewed consumer organizations and householders who have serious reservations about the idea that energy companies can intervene in domestic practices. A representative of a consumer organisation argued that it would not be very sensible if energy providers would be able to steer cooking practices:

> People are certainly not going to wait until 11 (p.m.) to put a pizza in the oven or a ready-to-serve meal in the microwave.

While this statement may indicate a more general suspicion towards any kind of intervention by energy providers, it seems reasonable to state that some practices are more 'open' to external modes of steering than others. Indeed intervening in cooking practices seems more intrusive than intervening in, for instance, food conservation practices (e.g. optimising energy use by fridges or freezers).

Yet, control and surveillance could also work the other way around. A number of interviewees stressed the potential of smart energy technologies to disclose information about energy providers to consumers as a potential form of 'counter-surveillance'. According to the consumer organisation, consumers could, for instance, benefit from smart meters that measure "*the spikes and dips and trends*" in power supply. Knowledge about energy distribution and supply could help consumers and consumer organisations to keep a check on energy providers and to "*unravel the world of energy*". Again, this shows that smart energy technologies are not neutral technologies, not from a provider perspective, nor from a consumer perspective. Instead, they are engaged in a dynamic interplay of consumer-provider power relations, which has consequences for the ways in which domestic practices can be steered externally (Naus et al. 2014).

4.3 Information Sharing Between Householders

Over the last decade citizens are discovering and exploring new ways to cooperate at the local level, increasingly also in smart grid environments. By doing so they run into various social and technical issues where information plays an important role. Meanwhile, institutional players are worried about the new non-expert based forms of energy-governance and establish new intermediary institutional actors to establish functional linkages to the decentralised initiatives. In this process, the governance of information flows emerges as a central concern. Here we present data from two surveys, one (N = 75) among members of Duurzame Energie Haaren (DEH), an energy cooperative that is working closely together with the regional Grid Operator Enexis (Sedee 2015), and a survey (N = 212) among householders sampled from a list of subscribers of an online sustainability newsletter. A small group of respondents in this latter survey participated in a focus group session (held

in April 2014) to discuss energy practices and privacy issues in the smart grid (Naus et al. 2015).

Together with the energy cooperative DEH, the regional grid operator Enexis has initiated a project entitled "Together Smart with Energy". The aim is to acquire a better understanding of the flexibility of people's energy use to reduce peaks in electricity demand. In this project, members are provided with a smart meter and an online platform that offers them real-time insight into their energy use. The online platform is also used to provide incentives and to experiment with the time-shifting of energy use.

In the survey, members of DEH were asked to express their opinions about interactions with other participants. In one of the questions the members were specifically asked whether they would participate in different forms of information and knowledge sharing. As can be seen from Fig. 3, answer categories ranged from "information sharing with friends at home" to "information sharing on an open internet platform".

Figure 3 reveals that there was clear preference for information sharing through scheduled theme-evenings that involve energy experts. This may indicate a couple of things. First, it suggests that expert knowledge is seen as a valuable contribution to interactions between members. Second, and perhaps more interestingly from a social perspective, this outcome also suggests that most people would rather exchange information and ideas in such a setting (an organised theme-evening) than on an internet platform which is more anonymous, or in small groups with relatives which is less anonymous. The social setting thus plays an important role when it comes to information sharing, and it is likely to affect the potential for learning about ways to save energy and to use it more sustainably (Sedee 2015).

The survey among subscribers of a sustainability newsletter revealed that information sharing is not a completely novel practice. Many of the respondents have shared information about energy use before, for instance by comparing energy consumption levels with family members (57 %) or with their neighbours (34 %). It may therefore not be surprising to find that new opportunities for information sharing were generally met with enthusiasm. For instance, the majority of

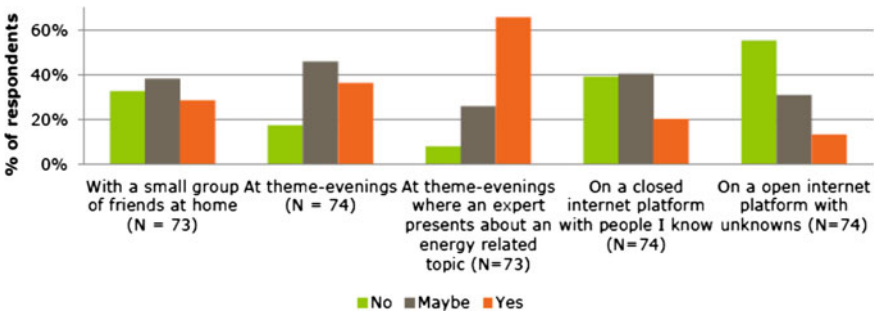

Fig. 3 Willingness to participate in information sharing practices amongst members of DEH (*Source* Sedee 2015, p. 77)

respondents would be willing to share their energy-performance through social media, with family and friends (60 %), while 69 % would be happy to enrol in a local energy-saving program. On the other hand, an energy saving competition (32 %) seemed less appealing, as this would imply competing with other households rather than helping each other out.

The survey also exposed that, for this group of respondents, information sharing between households serves as a welcome alternative to smart meter based energy advice by providers. Several respondents stated that they oppose the use of smart meter data "for commercial purposes", that they are afraid of being watched, or that they prefer interpreting smart meter data themselves. As opposed to expert advice, citizen-led initiatives were praised for the absence of a profit-orientation and for the possibility of "generating innovative ideas". The fact that such an initiative "originates from the users", rather than from an energy provider, is thought to take away the obligation to disclose information, as with the smart meter, and the possibility to use the information for commercial or administrative purposes.

The follow-up focus group sessions shed some more light on information sharing. Though participants initially expressed their enthusiasm about the unexplored opportunities of user-initiatives they also identified some undesirable consequences and limiting features. One of the focus group discussions clearly illustrated this:

Participant 1	"*The ideal situation, I think, is that everyone has a [carbon] footprint [that is visualised] near the front door of their house. Then everyone can see: this is how I did today*"
Researcher	"*Visible for others as well or...*"
Participant 2	"*Haha, A big cross! Misbehaving household, haha!*"
Participant 1	"*Haha, no, not on the outside! No, no, only when you enter your house. Only for yourself*"

This example shows that energy-related information is not only 'energy revealing' but also 'socially revealing'. The social judgement ("misbehaving") that may come along with information disclosure can form a limiting feature to information sharing practices So, similar to information flows between households and energy providers, care is also required regarding what energy-related information is shared among households (Naus et al. 2015).

5 Conclusion

The purpose of this chapter was to demonstrate the relevance of our conceptual framework through its application to recent and ongoing research on smart grids. A quantitative and qualitative assessment of smart meter trials and energy cooperatives in the Netherlands has allowed us to illustrate concepts of e-practices and

information flows empirically. We would argue that the framework can sensitise smart grid researchers to study the ways in which new energy and information flows transform routines, rhythms, and practices of household members and their relationships with service providers and other households.

The findings presented here show that newly generated information flows in smart grid configurations may help householders to change their routines and practices. On the other hand, the same information flows can also redefine the relationships within households (as in the example of parents monitoring their children's activities through their energy use), between households (as in the case of information exchange for energy conservation), and between households and energy providers (e.g. when consumers obtain information about provider performances). Smart energy systems therefore do not produce new e-practices in linear ways. Instead, these systems co-evolve with existing domestic practices and norm sets in a dynamic socio-technical setting.

6 An Unfolding Research Agenda on Smart Energy Systems and e-Practices

Social scientific research on domestic practices and smart energy configurations is unfolding rapidly. The research presented in this chapter has given a taste of the themes, concepts and dynamics at play. In this section we spell out some of the work that is currently underway and some of the research challenges ahead.

First, there is a need for further theoretical development regarding the nature of energy practices and a need to connect practice-based research to other theories and concepts available in sociology. Theoretical development stretches from assessing the nature of energy practices (i.e. Strengers 2012), to whether and how they interconnect with other domestic practices (i.e. Powells et al. 2014) and with higher order concepts of 'energy citizens' (i.e. Goulden et al. 2014), 'lifestyles', and 'moral economies' (i.e. Hargreaves 2012) of the household and beyond. Equally promising is recent work on the intermediary processes, interfaces, and organisations (Grandclement et al. 2014) which organise consumer-utility interactions. Studies theorising the cultural, moral and political implications of smart energy configurations can further deepen our understanding of smart grid development. Such theoretical groundwork is required to sharpen the lenses through which social scientists can interpret and analyse the phenomena of co-evolving smart energy configurations and e-practices.

Second, there is a need for methodological innovation in practice-based research on energy systems. The methodological toolbox for traditional consumption studies (i.e. surveys, interviews) does not always match the scope and objectives of social practice research. Innovative methods are available and being developed for the study of domestic e-practices and the reconfiguration of energy infrastructures. With e-practices as the object of research, it does not suffice to focus on individuals

and their intentions, attitudes or doings. Rather, we concentrate on the fate of practices, their histories, and the meanings, materials and know-how they contain. It means that practice research requires methodologies of participant observation including 'shadowing' (the researcher moves along with practitioners through their practices and poses questions in the meantime), and focus groups and stakeholder dialogues including methods of 'co-creation' (consumers and providers design new infrastructure services together). Furthermore, investigating the long term co-evolution of e-practices and energy infrastructures requires historical analysis (e.g. document studies or oral histories), longitudinal studies as well as future scenario and back-casting studies. Lastly, internationally comparative research will strengthen the understanding of practice dynamics in different socio-economic settings.

Third, there is a need to look across disciplinary boundaries and find more integrated ways of considering the potentials and pitfalls of smart grid development. This might be a significant challenge, as practice-based research is oftentimes positioned as fundamentally different from for instance psychological, economic and engineering perspectives. Yet, the development of a common ground is necessary to benefit from different insights and to better facilitate the role of households in this sustainability challenge. An integrated understanding of smart energy systems involves technology design, business model development, ethnographies of the home, behavioural modelling, policy assessments in equal measure. For example, only interdisciplinary work can produce a comprehensive understanding of how new domestic energy storage technologies shape—and are shaped by—behavioural patterns, power relations between consumers and utilities, and energy policy developments.

To conclude this research agenda, we would like to briefly mention two of our own research lines on smart energy systems. First, we are further examining the role of information flows in changing domestic e-practices. This is done, for instance, through a case study of 'Smart grid Lochem', a real-life smart grid pilot in the Netherlands. The pilot revolves around a local energy cooperative, LochemEnergie, which facilitates renewable energy generation and information exchange among its members. The study is inspired by the idea that the frequently articulated logic 'to measure is to know is to save energy' holds only limited explanatory power. Instead of being 'out there', waiting to be discovered, information may be better understood as something that is actively accomplished and put-to-work in and through practice. Accordingly, within this pilot setting we question when and how information is accomplished; when and how information is put-to-work; and how does the energy cooperative facilitate these processes?

Second, in the collaborative research project 'Emerging e-practices in the smart grid'[1] we are following the emergence and evolution of several e-practices. The project consists of four research themes: (1) New forms of monitoring and feedback

[1]Project 2014–2018 coordinated by Environmental Policy Group Wageningen UR, partnering with: TU Eindhoven, MilieuCentraal, Enexis and Demand-Centre Lancaster.

for improving domestic energy performances; (2) Provider- and consumer-controlled timing of renewable energy provision, storage and use in the household; (3) The embedding of new e-practices in existing mobility routines, and (4) Consumer engagement in public-private collectives for the (co)production of renewable energy at community-level. The ultimate aim of this research project is to reduce uncertainty about consumer uptake of e-practices and consumer appreciation smart energy systems.

As is clear from this research agenda, energy provisioning and domestic consumption comprise very dynamic fields of research. This implies that there are many methodological and theoretical challenges on the road. Yet, we believe it is worth taking up these challenges as they will reveal how new, sustainable e-practices and smart energy configurations emerge. This is important knowledge that energy planners, utilities, consumer organisations and policy makers will need in working towards a sustainable energy future.

Points for Discussion

- The chapter shows that e-practices can change but seldom according to a prescribed manner. How can policy-makers and energy providers incorporate these uncertainties in their strategies and investments to implement smart grids successfully?
- To what extent is the development of smart grids structure-dependent or actor-dependent? The structural side involves: technological framework, legal framework, institutional framework, political framework, economic framework (markets); the actor side is about who implements, operates, (mis)uses, exploits the structure to reassure its implementation and continuity.

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